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NAVAL POSTGRADUATE SCHOOL

Monterey, California



THESIS

RADAR MODEL WITH TERRAIN EFFECTS

by

James W. Meritt

March 1982

Thesis Advisor:

James K. Hartman

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Radar Model with Terrain Effects

by

James W. Meritt
Lieutenant, United States Navy
B.S., University of South Carolina, 1972

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

This thesis presents an interactive naval radar model which computes radar detection in the presence of land masses, using a parametric terrain description.

TABLE OF CONTENTS

I.	INTRODUCTION	- - - - -	9
II.	MOTIVATION	- - - - -	10
III.	MODEL	- - - - -	11
A.	WARFARE ENVIRONMENT SIMULATOR	- - - - -	11
1.	Basic System	- - - - -	11
2.	Radar Equation	- - - - -	11
3.	Signal Excess Model	- - - - -	13
4.	Conditions and Assumptions	- - - - -	15
B.	SMOLER-MILLS MODEL	- - - - -	16
1.	Basic System	- - - - -	16
2.	Terrain Model	- - - - -	17
3.	Elevation Routine	- - - - -	19
4.	Line of Sight Routine	- - - - -	21
C.	AUGMENTATION	- - - - -	22
1.	Introduction	- - - - -	22
2.	Input Routines	- - - - -	23
a.	Terrain Data	- - - - -	23
b.	Radar Data	- - - - -	24
c.	Target Data	- - - - -	25
d.	Other	- - - - -	25
3.	Computing Target Cross Section	- - - - -	28
4.	Beach Return Masking	- - - - -	28

5.	Main and Side Lobe Interference - - - - -	29
6.	Radar Shadowing - - - - -	31
a.	Case 1- - - - -	31
b.	Case 2 - - - - -	31
c.	Case 3 - - - - -	31
7.	Display Routine - - - - -	32
8.	Rerun with Changed Data - - - - -	35
IV.	FUTURE - - - - -	37
A.	POSSIBLE UTILIZATION OF MODEL - - - - -	37
B.	FUTURE ENHANCEMENTS - - - - -	37
	APPENDIX A: PROGRAM LISTING - - - - -	39
	APPENDIX B: SUBROUTINE DIRECTORY - - - - -	73
A.	BEACH - - - - -	73
B.	BRTN - - - - -	73
C.	ECURVE - - - - -	74
D.	ELEV - - - - -	74
E.	ELEVG - - - - -	74
F.	GETSE - - - - -	74
G.	INPUT - - - - -	75
H.	INTRO - - - - -	76
I.	KOVER - - - - -	77
J.	LAND - - - - -	77
K.	LOS - - - - -	77

L.	OBGAIN	- - - - -	78
M.	\$PARS	- - - - -	78
N.	RANGE	- - - - -	78
O.	RMAP	- - - - -	79
P.	SELECT	- - - - -	79
Q.	SETUP	- - - - -	79
LIST OF REFERENCES			- - - - - 81
BIBLIOGRAPHY			- - - - - 82
INITIAL DISTRIBUTION LIST			- - - - - 83

LIST OF TABLES

1.	Ducting Factor	- - - - -	13
2.	Required Radar Data	- - - - -	25
3.	Target Data	- - - - -	25
4.	Environmental and Probabilistic Data	- - - - -	25

LIST OF FIGURES

1.	Terrain Structure - - - - -	20
2.	Flow Chart - - - - -	23
3.	Initial Conditions - - - - -	27
4.	Geometric Area - - - - -	30
5.	Symbology for Plot - - - - -	33
6.	Screen Display - - - - -	34
7.	Menu Selection - - - - -	36

I. INTRODUCTION

This thesis presents a novel naval radar model which computes radar detection in the presence of land masses. The model is an interactive computer program which accepts scenarios and radar parameters from the user and displays a map of the area indicating where targets can and cannot be detected. The resulting map can be displayed at the user's computer terminal or printed offline.

Major capabilities of the model are:

1. parametric terrain description
2. user friendly input and output
3. beach return masking
4. radar shadowing
5. side lobe masking

The program is written in FORTRAN IV H (extended), to be executed on an IBM 3033 using an IBM 3278.2 video computer terminal. A data file which contains a parametric terrain description must be prepared before using this program, but all other required input is prompted at the terminal.

II. MOTIVATION

The Warfare Environment Simulator (WES) used by Command, Communications, and Control personnel is a large scale computerized naval wargame. The land displayed by the system does not affect the radar detection probabilities. This is one of the artificialities in the game.

During Exercise BRIGHT HORIZON '81 the tactic of concealing small vessels in fjords and among islands to prevent radar detection until a surprise attack could be made was demonstrated to be effective. This technique, while it could be anticipated, can not currently be modeled in WES.

North Atlantic Treaty Organization naval warfare scenarios virtually always include the proximity of land. United States Navy scenarios are primarily open ocean. It seems necessary to incorporate NATO problems into USN procedures. With this in mind, a method of encoding terrain data was combined with a radar model to produce a method of producing maps of the area in question with the concealed areas displayed.

III. MODEL

A. WARFARE ENVIRONMENT SIMULATOR

1. Basic System

WES is a computer program that simulates a naval warfare environment in a large computer system, enabling personnel to engage in realistic wartime scenarios without the expense of actually losing ships and lives [Ref. 1].

2. Radar Equation

The WES model uses the standard radar equation modified to handle ducting and clutter effects. Equation (1) is used to calculate signal excess.

$$SE = Pt + 2G + 2W + TCS - 4DR - B - NF - L - C \quad (1)$$

SE = signal excess, dB

Pt = peak transmitted power, dB//w

G = antenna gain, dB

W = wavelength, dB//cm

TCS = target cross section, dB//m

D = ducting factor

R = target range, dB//nm

B = receiver noise figure, dB

NF = noise factor, dB

C = clutter factor, dB

L = system loss factor, dB

System loss factor includes antenna pattern loss and atmospheric absorption loss. Antenna pattern loss takes into account the change in illuminating energy levels brought about by the lobe shape of the radar main beam pattern. The internal system losses are assigned to be 1.5 dB, a typical value for most radars. Atmospheric absorption loss is added to this. Atmospheric absorption loss is frequency dependent, and is assigned as 1 dB around 300 MHz and 3.5 dB at 5000 MHz, at target ranges typical to naval radars.

The clutter factor describes the losses due to sea clutter. It is taken to be $10\log(Hw)$, where Hw is the significant wave height in feet.

The ducting factor is used to describe the effects of ducted propagation, especially surface evaporation ducts. An approximate fit of the IREPS model of a leaky wave guide is used.¹ A strength of zero indicates no ducting, and a radar horizon limitation is evoked. If a duct is present, this restriction is lifted. A strength of five corresponds

¹Integrated Refractive Effects Prediction System, developed by Naval Ocean Systems Center and implemented on the Hewlett-Packard model 9845 desktop calculator. It is a shipboard environmental data processor and display system designed to aid in the assessment of the impact of lower atmospheric refraction effects on Naval EM systems.

to a "perfect", lossless duct with free space propagation within its boundaries. Values for D are selected from Table (1).

Table 1: Ducting Factor

strength	0	1	2	3	4	5
D	1.0	1.35	1.20	1.11	1.05	1.0

The noise factor is used to include jamming. It is not used in this model.

See subsection 3 below for the method of processing signal excess. The method used in determining the radar target cross section of ships is discussed in Chapter III, section c, subsection 3.

For this model an additional term is included. The "obstacle gain" is calculated and subtracted from the right hand side of the equation.²

3. Signal Excess model

Signal excess is converted to probability of detection on the basis of false alarm number and pulse integration as discussed below.

False alarm number is the number of radar signal pulses that are received before a non-signal noise pulse is

²For obstacle gain see chapter III, section c, subsection 6.

received. WES, as well as this model, offers the use of four different values.

The number of pulses illuminating the target is evaluated by use of equation (2).

$$N_p = \frac{60 (PRR) (BW)}{(SW) (ARR)} \quad (2)$$

where:

N_p = number of pulses

PRR = pulse repetition rate, pulses per second

BW = horizontal beam width, in degrees

SW = angular width of swept sector, in degrees

ARR = scan rate, in scans per minute

The distribution of signal excess can be closely approximated by a normal distribution with a mean defined by the number of pulses integrated, probability of false alarm, and a standard deviation of 7dB. A large table contains the mean of the signal excess distribution (μ) in terms of number of pulses integrated and probability of false alarm.

Conversion of computed signal excess (SE) to probability of detection is accomplished in WES as follows.

The signal excess is normalized by equation (3).

$$z = (se - \mu) / sd \quad (3)$$

The z is used to enter a table of cumulative standardized

normal values to get the probability of detection which is used in the WES simulation.

This model runs the process in reverse: given the desired probability of detection, the number of pulses, and an assumed standard deviation the standardized normal probability distribution is used to find a corresponding signal excess, which can then be compared to the realized signal excess to determine if the target will be detected within the constraints given.

4. Conditions and Assumptions

A number of constants are established in the WES model, as well as in this modified version. Many of them will be discussed in the sections in which they are singularly appropriate, but some of the more general ones will be mentioned here.

A $4/3$ earth radius is used in calculating the distance to the radar horizon to compensate for standard atmospheric refraction.

Receiver noise figure is taken as a constant value of 5.5 dB, a value which is primarily thermal noise under standard conditions.

The return from land is not directly modeled. The geometrical cross section of a portion of parametrized

terrain is assumed to be the radar cross section. Data is unavailable on the reflectivity of varying types of surface to compute the true radar cross section given the geometric cross section, so a reflectivity of 1 is assumed. A slope of at least .02 is required for beach return, when checking from the seaward side, and a slope of at least .3 is required for return in the sidelobes. In either case, the land must be at least as high as the target vessel. These values were determined by experimenting with the geometrical cross section of a terrain sample. The steeper slope required for the sidelobe masking is caused by the lower gain present in the sidelobe.

B. SMOLER-MILLS MODEL

1. Basic System

In 1979 Josef Smoler wrote his Master's thesis on an "Operational Lanchester-Type Model of Small Unit Land Combat" [Ref. 2]. It is a time sequenced, deterministic, battalion-level, force-on-force model implemented on a digital computer. It contained a method of modeling terrain developed by Christopher James Needles in March, 1976 for his Master's Thesis "Parameterization of Terrain in Army Combat Analysis" [Ref. 3]. In September 1980 Glenn M. Mills attempted to overcome shortfalls in the original model, and

added several enrichments to provide added user flexibility [Ref. 4]. A user's manual is provided for this model on a permanent disk in the W. R. Church Computer Center. These Fortran programs conduct their Army battles over land, using Needles' terrain model and Professor Hartman's elevation and line-of-sight routines.³ These routines were used to model the land in this naval model. Only minor modifications were required, partially to adjust to the change in scale and partially to remove some strictly land effects.

2. Terrain Model

In 1976 Christopher James Needles presented and evaluated a methodology of parameterizing terrain for use in land combat analysis [Ref. 3]. This was a shift from the traditional method of digitizing data compiled from terrain and interpolating. He described a method by which terrain could be created mathematically by using a modified bivariate normal probability density function.

The common form of the bivariate normal density function is given by equation (4).

³See sections three and four of this chapter for ELEV and LOS.

$$f(x, y) = \frac{1}{2\pi\sigma_x\sigma_y(1-\rho^2)} \exp \left\{ -\frac{1}{2(1-\rho^2)} \left[\left(\frac{x-\mu_x}{\sigma_x} \right)^2 - 2\rho \left(\frac{x-\mu_x}{\sigma_x} \right) \left(\frac{y-\mu_y}{\sigma_y} \right) + \left(\frac{y-\mu_y}{\sigma_y} \right)^2 \right] \right\} \quad (4)$$

The equation has been modified by making the normalizing constant equal the the maximum elevation of the desired terrain. The resulting equation has sufficient parameters to model many different types of "hills", and by carefully combining these hills different types of terrain can be modeled.

This method of terrain modeling is currently being used by the STAR model written in SIMSCRIPT II.5, but the Fortran version of the method has also been used, in the Smoler-Mills model previously described.*

See Figure (1) for an illustration on how the hills are constructed.

3. Elevation Routine

The purpose of the function ELEV is to compute terrain elevation for given X, Y coordinates.

The elvation routine was initially provided to Josef Smoler by Professor James K. Hartman for use in his land combat model, and subsequently by Mills in his modification of Smoler's model [Ref. 5].

The point defined by the coordinates is examined to determine if any of the "hills" are present, and if so which

*Simulation of Tactical Alternative Response, a ground-air combat model developed at the Naval Postgraduate School.

the shape of the hills from above is
modified by the correlation coefficient

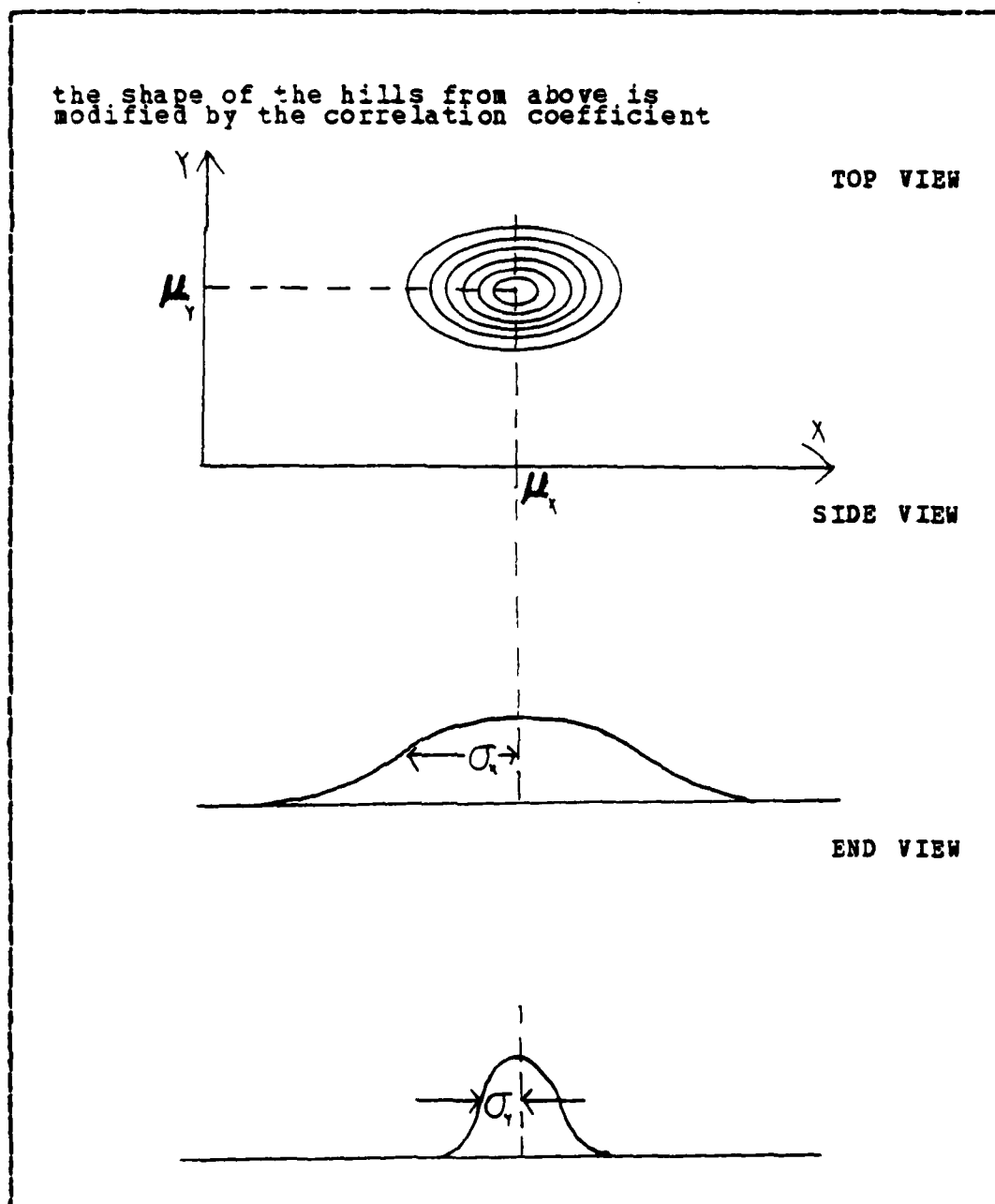


Figure 1: Terrain Structure

ones. Only those which are effective are evaluated, minimizing the computer time required for each point. Given the

index of the "effective hill", the appropriate parameters are selected and applied to the previously defined modified bivariate normal distribution to derive the terrain elevation at that point.

In a second elevation routine, ELEVG, the gradient components of the equation are computed as well as the elevation, allowing the slope to be determined easily.

The procedure to add tree height to the top of the hills to increase elevation has been removed for this radar model.

4. Line of Sight Routine

The line-of-sight routine was also developed by Professor Hartman [Ref. 5]. Its development and use follow closely those of the elevation routines.

Line of sight (LOS) is a purely geometric computation assuming perfect visibility. The result of the LOS computation was initially the percent of the vertical height of the target visible to the searcher, and the percent visible of the searcher by the target. In addition, the range and elevation of the point which causes the target to be totally obstructed is now returned.

The basic procedure is: "Find the lowest sight line from the searcher over the terrain. Extend this line to the

target's position and compare its extrapolated height to the target's elevation. Thus compute the percent visible."

In as much as the searcher and the target are both ships, the searcher is assumed to be at sea level. If ducting is present, the target is also assumed to be at sea level. If ducting is not present, an additional routine computes the amounts by which both the obstructing terrain and the target are lowered by the earth's curvature.

As in ELEV, forest calculations have been removed.

C. AUGMENTATION

1. Introduction

The STAR LOS and ELEV routines have been combined with the WES radar equation to get a routine to calculate detection behind and next to land.

A separate routine was written to calculate beach effects, side lobe effects, and a special routine to provide output on an IBM 3278 computer video terminal.

After accepting preliminary terrain, radar, target, and environmental data the program samples sites a designated distance apart from a specified reference point to create a matrix containing either elevation or detection data, to be examined at the terminal, with an option to print it on a line printer.

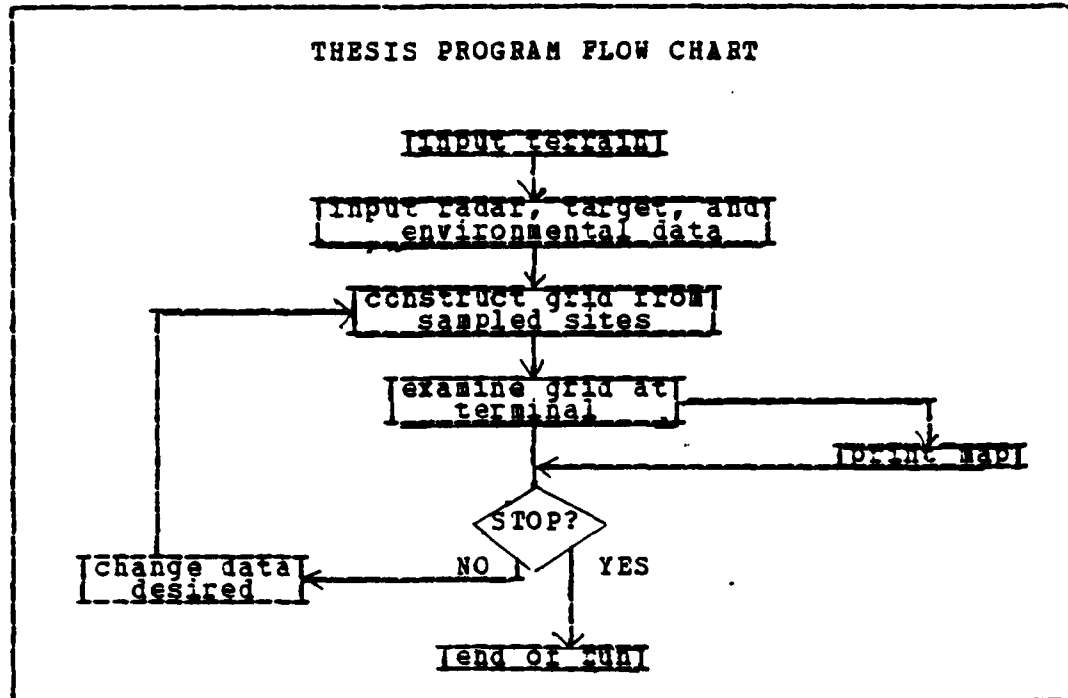


Figure 2: Flow Chart

Figure (2) presents a flow chart of the overall program.

2. Input Routines

The following subroutines were developed to input the information required by the programs.

a. Terrain Data

A number of different items are required to define the terrain. The elevation of the reference plane must be entered, along with the total number of "hills". For each hill, the X and Y coordinates, its maximum elevation, the standard deviation in both the X and Y direction, and

the correlation between them must be entered for each hill. This defines the hill, in as much as these are the appropriate parameters in the bivariate normal distribution described in the section on the terrain model.⁵

The data for the terrain is assumed to be contained in a data file accessible by the virtual machine. Two routines adapted from ones written by Mark L. Yount perform the necessary file definitions, after requesting filename, filetype, and filemode (filemode defaults to a) at the terminal.

Information for up to 100 hills covering over an area 200nm by 200nm may be entered this way.

b. Radar Data

Radar information may be entered in either of two ways: First, it may be stored in a data file, and loaded similar to the method utilized to load terrain data. Second, it may be entered at the terminal, in response to questions on the screen. Table (2) lists the information required.

⁵For BVN equation used in the terrain model, see chapter III, section B, subsection 2.

Table 2: Required Radar Data

NAME OF RADAR SYSTEM
PEAK TRANSMITTED POWER (WATTS)
RECEIVER IF BANDWIDTH (MHZ)
PULSE REPITION RATE (PPS)
HORIZONTAL BEAM WIDTH (DEGREES)
VERTICAL BEAM WIDTH (DEGREES)
ANGULAR WIDTH OF SWEPH SECTOR (DEGREES)
SCAN RATE (SPM)
PULSE LENGTH (MICROSECONDS)
FREQUENCY (HERTZ)
ANTENNA HEIGHT (FEET)
S-E COORDINATES OF RADAR (NM)
NUMBER OF LOBES (UP TO 5)
STRONGEST # LOBES (DEGREES CW FROM MAIN LOBE)

(note: the "*" above represents the number of lobes desired)

c. Target Data

The target data is entered in the same subrout-
ine. Table (3) lists the required information.

Table 3: Target Data

IDENTIFIER FOR TARGET
VERTICAL SIZE OF TARGET (FEET)
TARGET MAXIMUM DISPLACEMENT (KILOTONS)

d. Other

Additional information is required for the pro-
gram. It consists of environmental and probabilistic data.

Table 4: Environmental and Probabilistic Data

DUCTING STRENGTH (INTEGER-0 FOR NO DUCT TO 5 FOR PERFECT DUCT)
PROBABILITY OF FALSE ALARM
REQUIRED PROBABILITY OF DETECTION FOR SINGLE SWEEP
SIGNIFICANT WAVE HEIGHT (FEET)

Table (4) lists these additional requirements.

A copy of initial conditions is then available to be printed on the line printer upon request. Figure (3) is an example of this listing.

```

SPS-55 RADAR
=====
PEAK TRANSMITTED POWER:
ANTENNA GAIN:
FREQUENCY:
RECEIVER NOISE FIGURE:
HORIZONTAL BEAM WIDTH:
VERTICAL BEAM WIDTH:
SCAN RATE:
PULSE LENGTH:
PULSE REPETITION RATE:
PULSES ON TGT PER SWEEP
MINIMUM RANGE:
STRONGEST 2 LOBE(S) (DEGREES CW):
MAXIMUM UNAMBIGUOUS RANGE:
TARGET: KANIN
=====
TARGET MAXIMUM DISPLACEMENT:
VERTICAL SIZE OF TARGET:
TARGET RADAR CROSS-SECTION:
ENVIRONMENTAL DATA:
=====
SIGNIFICANT WAVE HEIGHT:
DUCTING STRENGTH
0 FOR NO DUCT UP TO 5 FOR PERFECT DUCT
DUE TO DUCTING, THERE IS NO RADAR HORIZON
HILL 1 IS
DETECTION DATA
=====
PRCBABILITY OF FALSE ALARM
PROBABILITY OF DETECTION

```

1.30E+05 WATTS
3.14 DB
1.00E+10 HERTZ
0.08 DB
1.50 DEGREES
20.00 DEGREES
16.00 RPM
1.00 MICROSECONDS
750.00 PPS
0.08 NM
45 315
109.26 NM
4.60 KILOTONS
52.50 FEET
5.13E+04 SQ METERS
3.00 FEET
5
150.00 150.00
1-E-4
0.30

Figure 3: Initial Conditions

Finally, information relevant to the actual plotting is requested. Simply enter the number of nautical miles between sample points desired and a reference point on the overall map and the routine commences its calculations.

3. Computing Target Cross Section

The Target Characterization Branch of the Naval Research Laboratory has made carefully controlled measurements of the radar cross sections of a number of naval ships. A simple empirical expression has been obtained (see equation (5)) that expresses the cross section as a function of the displacement and the frequency.

$$tcs = 52f^4 d^3 \quad (5)$$

Where:

tcs = Target cross section in square meters

f = radar frequency in megahertz

d = displacement in kilotons (full load)

This expression provides reasonable approximations for the microwave band common to most naval radars, and over the displacement range of 2000 to 17000 tons [Ref. 6].

4. Beach Return Masking

Each segment of land (elevation greater than 0.5 meters) is checked to determine if it is a beach. This is done in subroutine BEACH by checking every adjacent sample

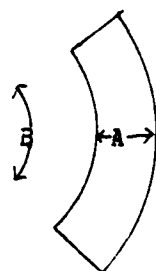
point in the grid and determining if any of them is ocean (elevation less than 0.5 meters). If this is the case, it is assumed that a potential target can get next to it. Next subroutine BRTN estimates the geometric cross section of a section of beach. This is done by first determining the area within one resolution cell. The size of the cell is determined by taking the area between two circles at the given range separated by the range resolution and between two radial lines separated by the angular resolution. Subroutine ELEVG is then called to determine the slope of the section of beach at the point of concern as seen by the radar. The effective area of the resolution cell is determined by taking the sine of this slope and multiplying it by the resolution cell total area. See Figure (4) for an illustration.

If the effective cross section determined in the above manner is greater than that of the target vessel, it is assumed that any return from the beach would mask the return from the target.

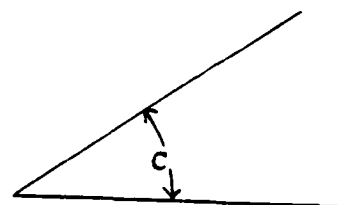
5. Main and Side Lobe Interference

LAND is a subroutine which checks the main lobe and given major side lobes for the presence of land. A procedure similar to BEACH is used to determine the proximity of

A is range resolution
 B is angular resolution
 C is angular resolution



TOP VIEW



SIDE VIEW

Figure 4: Geometric Area

land, and once this is established ELEVG is used to check if there is sufficient slope for radar return.

Side lobes are checked by using ELEVG to check for land at the same range as the point to be evaluated in the direction of a major lobe when the target is centered in the side lobe.

The presence of land of sufficient height and slope in any of the inspected locations indicates that masking takes place.

6. Radar Shadowing

After calling the line-of-sight routine, the program treats the contact in one of three ways:

a. Case 1

There is no obstruction. The obstruction gain is set to zero.

b. Case 2

There is only partial obstruction. The target is at the interface between shadow and illumination. The obstacle gain is set at the log of an eighth, in accordance with the basic optical interference technique. [Ref. 7]

c. Case 3

The target is totally obstructed, in which case the subroutine OBGAIN is called to determine obstacle gain.

OBGAIN calculates the "obstacle gain" created by the radio waves being diffracted over the hill tops. A "knife edge" obstacle is assumed, and the calculations are performed using Picquenard's radio wave propagation equations [Ref. 3]. If the hill is not the highest of the radar, the hill, and the target it is assumed that the target is again at the interface and the same value mentioned earlier is returned, otherwise the calculations continue.

In any case, the obstacle gain is treated as an attenuation and subtracted from the other values in the equation used to calculate signal excess.

7. Display Routine

RMAP is a version of TMAP modified to allow the use of special symbols. TMAP has been submitted for the NONIMSL LIBRARY at NPS. The routine interactively takes an array and prepares a contour map for the vicinity of a given point. The output is on a terminal or on the printer, at the option of the user, interactively taking input from the keyboard.

Passed arguments: A is the array to be plotted

N and M are its dimension

SPNM is the number of nautical miles
between points.

Other arguments are requested at the terminal. the program is a modified version of Professor Gilles Cantin's program CTRMAP version of OCT 1, 1969, adapted for terminal use.

Figure (5) is given on the screen immediately before commencing the plots, either initially at the terminal or printed at the top of the paper printout.

```

THERE ARE 1.00NM BETWEEN POINTS
O= 0.0
A= 2.000
P= 12.000
Q= 22.000
V= 32.000
$=RADAR

B= 4.000
G= 14.000
R= 24.000
W= 34.000
*=MASKED

C= 0.0
H= 6.000
S= 16.000
Y= 26.000

D= 8.000
I= 18.000
T= 28.000
Y= 38.000

E= 10.00
J= 20.00
U= 30.00
Z= 40.00
0.4000000E+02

```

Figure 5: Syabology for Plot

Note: On Figure (6), the "\$" representing the radar's position is off the screen.

Figure (6) is an example of what appears on the terminal. The paper listing gives the entire map area, with symbology as before.

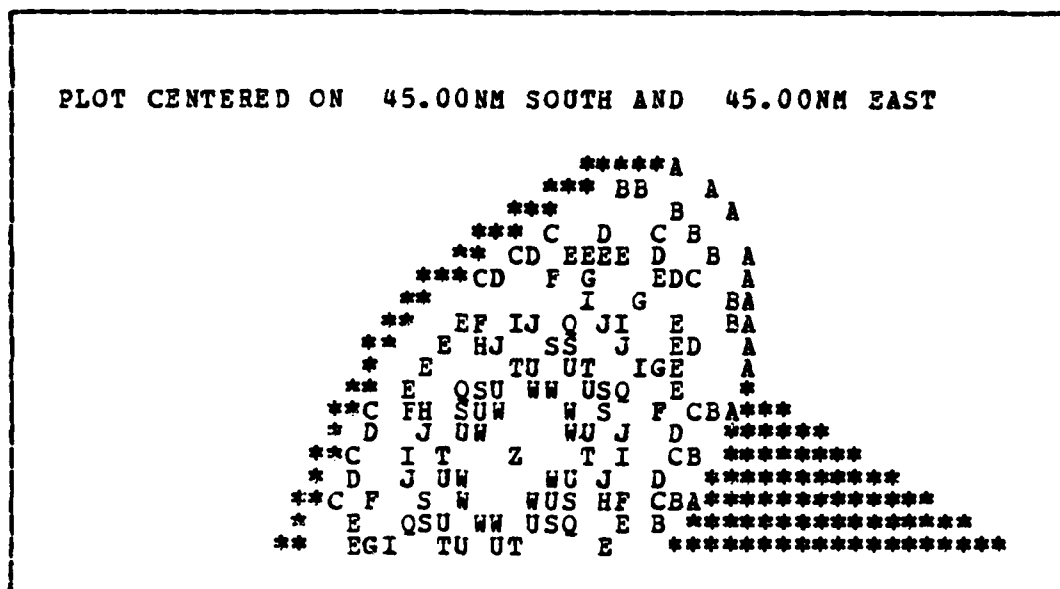


Figure 6: Screen Display

In the screen display given, the points are one nautical mile apart, with the radar located approximately 20nm to the northwest of the center of the island. The letters roughly centered in the screen correspond to terrain elevation, as coded in Figure (2). The '*' on the left edge correspond to a steep beach, where the beach return is stronger than the reflection from the target. The '*' to the right define the area shadowed by the island. The clear area around it is sea level.

8. Rerun with Changed Data

This routine allows the model to be rerun after changing a select number of the parameters. Figure (7) is the screen display which is the menu of allowable changes. Simply enter the number corresponding to the desired change and then the new value. The routine will offer to print the new parameters and then construct another matrix containing elevation and detection data for examination.

TERRAIN HELD CONSTANT

- | | |
|--------------------------|--------------------------------|
| 1- NAME OF RADAR | 11- ANTENNA HEIGHT |
| 2- PEAK POWER | 12- RADAR COORDINATES |
| 3- BANDWIDTH | 13- TARGET NAME |
| 4- PRR | 14- TARGET SIZE |
| 5- HORIZONTAL BEAM WIDTH | 15- TARGET DISPLACEMENT |
| 6- VERTICAL BEAM WIDTH | 16- DUCTING STRENGTH |
| 7- SECTOR SIZE | 17- PROBABILITY OF FALSE ALARM |
| 8- SCAN RATE | 18- PROBABILITY OF DETECTION |
| 9- PULSE LENGTH | 19- WAVE HEIGHT |
| 10- FREQUENCY | 20- END OF CHANGES |

Figure 7: Menu Selection

IV. FUTURE

A. POSSIBLE UTILIZATION OF MODEL

This model has applications in planning and training for Naval Operations.

For training purposes, this model could be incorporated into WES or other sea combat models to better reflect detection in areas where land is present. For such uses, the input and display routines could be trimmed, and only the point in question would be analyzed, not an entire map array.

For planning purposes, ship courses could be selected to provide maximum radar protection from land shadowing, or the inverse, to allow minimum terrain interference for stationing radar guard ships, could be found after parameterizing the applicable areas.

B. FUTURE ENHANCEMENTS

Parabolic cylinders could be utilized to model the refraction effects instead of knife-edges to improve the model somewhat [Ref. 9].

The input and output routines could be modified to take better advantage of facilities available (plotting terminals, for instance).

A method to find the beach, instead of identifying if a particular point is within a given distance of the sea, would enable better coastal coverage.

Radar return is often observed behind obstacles under conditions in which simple knife-edge refraction cannot be responsible. The causes for these effects should be found and incorporated into the model.

For use in other models, different subroutines may be adapted for the particular model being constructed. Some subroutines will have to be entirely rewritten, especially those involving beach return which use mapped data already calculated, to handle single-point problems.

APPENDIX A

PROGRAM LISTING

The following is an entire listing of the radar model. It has been specially written to be run on the IBM 3033 on a IBM 3278.2 video terminal, the facilities available at the Naval Postgraduate School. Appendix B contains and explanation of each of the subroutines.

```

COMMON /IPRT/ IPRT
COMMON /HILLS/ XC(100), YC(100), PEAK(100), SX(100), SY(100), RHO(100)
COMMON /HILLS/ SCALE(100), TWOH(100), TWOH(100), BASE
COMMON /HILLS/ NHILLS
COMMON /CCUNTR/ KH, KHW, KV, KN, KGRS, KELL, KINT
COMMON /GRID/ LST(10,10), NHL(10,10), LISTH(450), KHREP(100), KTRP
COMMON /RADAR/ PT, G, W, B, RNP, RL, C, D, RMIN, RMAX, ARCS, RRES, LOBE,
+ALOE(5)
DIMENSION IGX(100), IGY(100), IEL(100), CS1(100), CS2(100), EA(350,350)
IPRT=1
CALL INTRO
WRITE (6,20)
FORMAT (10,20)
CALL SETUP
CALL INPUT (DSE,TCS,ISTR,HR,SIZEA,SIZEB,RX,RV,TMICA)
CONTINUE
CALL PRTCMS ('CLRSCRN')
WRITE (6,1)
FORMAT (5,*) SFNM
READ (5,*) SFNM
WRITE (6,120)
FORMAT (10,*) XREFNM, YREFNM
READ (5,*) XREFNM, YREFNM
XREF=XREFNM*1829.27
YREF=YREFNM*1829.27
NEA=INT((AMIN1(350./SFNM,350.))
SF=SFNM*1829.27
DO 5 I=1,NEA
DO 10 J=1,NEA
Y=(SP*FLOAT(I)) +XREF
Y=(SP*FLOAT(J)) +YREF
CALL ELEV(Y,Y,TMAC)
EA(I,J)=THAC
CONTINUE
CONTINUE
DO 100 J=1,NEA
DO 101 K=1,NEA
CHECK IF WITHIN RANGE
Y=(SP*FLOAT(J)) +XREF
Y=(SP*FLOAT(K)) +YREF
CALL RANGE (RY,RV,Y,Y,FAR)
IF (EA(J,K).LT.0.5.AND.FAR.GT.RMAX) GOTO 50
CHECK IF INSIDE MINIMUM RANGE
IF (EA(J,K).LT.0.5.AND.FAR.LT.RMIN) GOTO 50
CHECK IF IT IS A BEACH, AND IF THE TERRAIN IS ELEVATED AT LEAST
AS HIGH AS THE TARGET SHIP IS, CHECK FOR RETURN
KOST=0
IF (EA(J,K).GT.SIZEB) CALL BEACH (J,K,EA,NEA,NEA,KOAST)

```

20

500

15

1

120

10

5

C

C

C

C


```

502      GOTO 500
        CONTINUE
        STOP
        END
        SUBROUTINE ANSWER (K)
        REAL*8 ANS, Y/'YES'/'N/'NO '/'
        WRITE (6,2) ENTER YES OR NO'
        FORMAT (5,3) ANS
        READ (5,3) ANS
        FORMAT (1A3)
        IF (ANS.NE.Y) GOTO 4
        K=1
        RETURN
        IF (ANS.NE.N) GOTO 5
        K=0
        RETURN
        WRITE (6,6) ENTRY NOT RECOGNIZED'
        FORMAT (1
        GOTO 1
        END
        SUBROUTINE BEACH (IX,IY,A,N,M,KOAST)
        DIMENSION A(N,M)
        ROUTINE DETERMINES IF POINT OF LAND (POSITION IX,IY IN A)
        IS ADJACENT TO THE SEA. KOAST IS RETURNED
        IF KOAST=0 THE POINT IS INLAND
        IF KOAST=1 THE POINT IS ADJACENT TO THE SEA
        KOAST=0
        IXT=MAX(1,IX-1)
        IXB=MIN(M,IX+1)
        IYL=MAX(1,IY-1,1)
        IYR=MIN(N,IY+1)
        ALERT=1
        DO 5 I=IXT,IXB
        DO 10 J=IYL,IYR
        ALERT=ALERT+A(I,J)
        CONTINUE
        IF (ALERT.EQ.0.) KOAST=1
        RETURN
        END
        SUBROUTINE BRTN (X1,Y1,X2,Y2,ECS)
        COMMON /RADAR/PT,G,W,B,RNF,RL,C,D,RMIN,RMAX,ARES,RRES,LOBE,
        +ALOBE(5)
        ROUTINE CALCULATES EFFECTIVE RADAR CROSS SECTION OF AN AREA OF
        LAND THE SIZE OF A RESOLUTION CELL WHICH MIGHT CONTAIN A TARGET
        X1,Y1 ARE THE POSITION OF THE RADAR
        X2,Y2 ARE THE POSITION OF THE BEACH
        RRES IS THE RADAR RANGE RESOLUTION
        ARES IS THE RADAR ANGULAR RESOLUTION

```



```

      QY = (Y - YC(I)) / SY(I)
      QYSQ = QY * QY
      IF (QYSQ .GE. 9.) GO TO 100
      QXY = TWO*HO(I) * QY * QY
      FACTOR = SCALE(I) * (QYSQ + QXY)
      IF (FACTOR .LT. -3.) GO TO 100
      HT = PEAK(I) * EXP (FACTOR)
      IF (HT .LE. ZMAX) GO TO 100
      ZMAX = HT
100  CONTINUE
150  THAC = ZMAX
      IF (IPRT .GE. 20) WRITE(6,389) X, Y, THAC
389  FORMAT(' LEAVE SUBRTN ELEV: X = ', F8.0, ' Y = ', F8.0, ' THAC = ',
2      F12.6)
      RETURN
END
SUBROUTINE ELEVG(X, Y, THAC, GX, GY)
COMMON /HILLS/ XC(100), YC(100), PEAK(100), SX(100), SY(100), RHO(100)
COMMON /HILLS/ SCALE(100), TWO*HO(100), TWO*SCL(100), BASE
COMMON /HILLS/ NHILLS
COMMON /GRID/10/ LST(10,10), NHL(10,10), LISTH(450), KHREP(100), KTREP
DATA NGRID/10/ GSIZE/54878./
C FUNCTION TO COMPUTE TERRAIN ELEVATION (THAC) FOR GIVEN X, Y
C COORDINATES AND GRADIENT COMPONENTS GX AND GY.
      ZMAX = BASE
      GX = 0.
      GY = 0.
      IX = 1 + IPIX(X/GSIZE)
      IF (IX .GT. NGRID) IX = NGRID
      IY = 1 + IPIY(Y/GSIZE)
      IF (IY .GT. NGRID) IY = NGRID
      IF (NHL(IX,IY) .EQ. 0) GO TO 150
      LS = LST(IX,IY)
      LEND = LS + NHL(IX,IY) - 1
      DO 100 L = LS, LEND
      I = LISTH(L)
      QX = (X - XC(I)) / SX(I)
      QYSQ = QX * QX
      IF (QYSQ .GE. 9.) GO TO 100
      QY = (Y - YC(I)) / SY(I)
      QYD = QY * QY
      IF (QYSQ .GE. 9.) GO TO 100
      QXY = TWO*HO(I) * QX * QY
      SC = SCALE(I)
      FACTOR = SC * (QYSQ + QXY)
      IF (FACTOR .LT. -3.) GO TO 100
      HT = PEAK(I) * EXP (FACTOR)
      IF (HT .LE. ZMAX) GO TO 100

```

```

100 ZMAX = HT
150 GY=HT*SC*(2.0*QX+QY)/SX(I)
CONTINUE
200 TMAC=ZMAX
250 RETURN
300 END
SUBROUTINE GETSE (R,TCS,SE,OBGN)
ROUTINE PROCESSES RADAR DATA TO COMPUTE SIGNAL EXCESS RETURNED
TO RADAR FROM CONTACT UNDER SPECIFIED CONDITIONS
COMMON /RADAR/PT,G,W,B,RNF,RL,C,D,RHIN,RMAX,ARES,BRES,LOBE,
+ALOE(5)
TCSMOD=ALOG10(TCS)
RHOD=ALOG10(R/1829.27)
SE=PT+2.*G+2.*W+TCSMOD-4.*D+RHOD-B-RNF-RL-C-OBGN
RETURN
END
SUBROUTINE INPUT (SE,TCS,ISTR,HR,SIZEA,SIZEB,RX,RY,THICA)
COMMON /HILLS/ XC(100),YC(100),PEAK(100),SX(100),SY(100),RHO(100)
COMMON /HILLS/ SCALE(100),TWOH(100),TWOHCL(100),BASE
COMMON /HILLS/ NHILLS
COMMON /RADAR/PT,G,W,B,RNF,RL,C,D,RHIN,RMAX,ARES,BRES,LOBE,
+ALOE(5)
COMMON /RDR/RDR$,TGTS$,PRR,BW,BV,FREQ,SW,ARR,PL,DISP,HT,HW,PDET,PTR
COMMON /HILL/YMC(100),YMC(100)
REAL*8 RDR$,TGTS$,IPFS(4),E-4',E-6',E-8',E-10'/
DIMENSION ALOBES(5)
ROUTINE READS IN THE RADAR, TARGET, ENVIRONMENTAL, AND DETECTION
DATA, EITHER FROM THE TERMINAL OR FROM A DATA FILE.
IFRT=0
I=5
EQUATIONS TO DETERMINE SECONDARY RADAR CHARACTERISTICS FROM INPUT DATA
TAKEN FROM "HOW TO SPEAK RADAR" BY ARNOLD E. AIKER, VARIAN
ASSOCIATES REVISED JANUARY 1974
CALL PRCHS ('CLSCRN')
WRITE (6,300)
FORNAT (1) DOES A FILE EXIST WHICH HAS THE RADAR,TARGET,DETECTION',
+ , AND ENVIRONMENTAL DATA?'
CALL ANSWER (ITF)
IF (ITF.EQ.1) L=7
IF (ITF.EQ.1) CALL SELECT
CALL PRCHS ('CLSCRN')
IF (ITF.EQ.1) WRITE (6,350)
FORNAT (1) THE FOLLOWING INFORMATION IS BEING ENTERED:')
IF (ITF.EQ.0) WRITE (6,351)
FORNAT (1) ENTER THE FOLLOWING DATA:')
WRITE (6,22)
FORNAT (1 NAME OF RADAR SYSTEM')

```

```

23 IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,23) RDR$
   FORMAT (1A7)
   WRITE (6,1)
1   FORMAT (1, PEAK TRANSMITTED POWER (WATTS), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) PTR
   PT=10.*ALOG10(PTR)
   WRITE (6,3)
3   FORMAT (1, RECEIVER IF BANDWIDTH (MHZ), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) B
   B=ALOG10(B)
   WRITE (6,4)
4   FORMAT (1, PULSE REPETITION RATE (PPS), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) PRR
   WRITE (6,5)
5   FORMAT (1, HORIZONTAL BEAM WIDTH (DEGREES), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) BV
   WRITE (6,20)
20  FORMAT (1, VERTICAL BEAM WIDTH (DEGREES), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) BV
   ARES=15*ANGULAR RESOLUTION
   ARES=BW
   C   IS ANTENNA GAIN
   G=ALOG10(41252.962/(BW*BV))
   WRITE (6,6)
6   FORMAT (1, ANGULAR WIDTH OF SWEPH SECTOR (DEGREES), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) SW
   IF (ITP.EQ.0) CALL FRTCHS ('CLESCRN')
   WRITE (6,7)
7   FORMAT (1, SCAN RATE (SPH), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) ARR
   WRITE (6,8)
8   FORMAT (1, PULSE LENGTH (MICROSECONDS), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) PL
   WRITE (6,9)
9   FORMAT (1, FREQUENCY (HERTZ), 'SEC')
   IF (ITP.EQ.1) CALL FRTCHS ('CP','SL','1','SEC')
   READ (L,*) FREQ
   SIZEA=259792500./(BV*FREQ)
   WRITE (6,10)

```

```

10  FORMAT (' ANTENNA HEIGHT (FEET)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) HR
    THICA IS THE HEIGHT OF THE ANTENNA (IN METERS) FOR LOS
    THICA=.3048781*HR
    WRITE (6,90)
90  FORMAT (' NUMBER OF SIDE LOBES (UP TO 5)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) LOBE
    IF (LOBE.GT.5) LOBE=5
    IF (LOBE.LT.1) GOTO 95
    WRITE (6,91) LOBE
91  FORMAT (' STRONGEST .13. LOBES (DEGREES CW)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) (ALOBES(I),I=1,LOBE)
    DO 92 I=1,LOBE
92  ALOBE(I)=ALOBES(I)/57.295779
95  CONTINUE
    WRITE (6,70)
70  FORMAT (' S-E COORDINATES OF RADAR (NM)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) RX,RY
    RX=RX*1829.27
    RY=RY*1829.27
    W IS WAVELENGTH (DB/CH)
    W=ALOG10(2997925000./PREF)
    NP IS NUMBER OF PULSES ILLUMINATING A TARGET PER SWEEP
    NP=INT((60.*PRE*BW)/(SW*ARR))
    IF (ITP.EQ.0) CALL PRTCHS ('CLRSCRN')
    WRITE (6,24)
24  FORMAT (' IDENTIFIER FOR TARGET')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,23) TGT$
    WRITE (6,19)
19  FORMAT (' VERTICAL SIZE OF TARGET (FEET)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) HT
    SIZEB IS VERTICAL SIZE OF THE TARGET (IN METERS) FOR LOS
    SIZEB = HT*.3048781
    WRITE (6,11)
11  FORMAT (' TARGET MAXIMUM DISPLACEMENT (KILOTONS)')
    IF (ITP.EQ.1) CALL PRTCHS ('CP',SL',1',SEC')
    READ (1,*) DISP
    IF ((DISP.LT.2).OR.(DISP.GT.17.)) WRITE (6,12)
12  FORMAT (' WARNING: TARGET CROSS SECTION MAY BE IN ERROR')
    C AN EMPINICAL FORMULA FOR THE RADAR CROSS SECTION OF SHIPS AT
    C GRAZING INCIDENCE...IEEE MAR 74
    TCS=52.*SQRT(PREQ/1.E6)*DISP*.15

```

```

13 IF (ITP.EQ.0) CALL PRTCHS ('CLRSCRN')
14 WRITE (6,14)
   + DUCTING STRENGTH (INTEGER-0 FOR NO DUCT UP TO 5 FOR',
   + PERFECT DUCT)')
   + CALL PRTCHS ('CP','SL','1','SEC')
   + READ (L,*) ISTR
   + IF (ISTR.LT.0) .OR. (ISTR.GT.5) GOTO 13
   + APPROXIMATE FIT OF IREPS MODEL, AS USED IN W.E.S.
   + IF ISTR IS GREATER THAN 0, THE HORIZON CONSTRAINT IS REMOVED
   + IF (ISTR.EQ.0) D=1.35
   + IF (ISTR.EQ.1) D=1.2
   + IF (ISTR.EQ.2) D=1.1
   + IF (ISTR.EQ.3) D=1.05
   + IF (ISTR.EQ.4) D=1.0
   + IF (ISTR.EQ.5) D=1.0
   + IF ((FREQ.LT.19.E7) .OR. (FREQ.GT.12.E9)) .AND. (ISTR.GT.0))
   + WRITE (6,15)
   + WARNING: DUCTING MAY BE IN ERROR')
   + IF (ITP.EQ.1) CALL PRTCHS ('CLRSCRN')
   + WRITE (6,16)
   + PROBABILITY OF FALSE ALARM: '/' 1=E-4/' 2=E-6/'
   + 3=E-8/' 4=E-10/'
   + IF (ITP.EQ.1) CALL PRTCHS ('CP','SL','1','SEC')
   + READ (L,*) IPF
   + WRITE (6,21)
   + REQUIRED PROBABILITY OF DETECTION FOR SINGLE SWEEP')
   + IF (ITP.EQ.1) CALL PRTCHS ('CP','SL','1','SEC')
   + READ (L,*) PDET
   + IF (PDET.LT.1.0) GOTO 82
   + WRITE (6,81)
   + PROBABILITY MUST BE EXPRESSED AS A VALUE LESS THAN 1')
   + FORMAT (1)
   + GOTO 200
   + CONTINUE
   + CALL PD22SE (SE,IP,IPF,PDET)
   + SE IS THE SIGNAL EXCESS REQUIRED TO GIVE THE DESIRED PDET
   + WRITE (6,17)
   + SIGNIFICANT WAVE HEIGHT (FEET)')
   + IF (ITP.EQ.1) CALL PRTCHS ('CP','SL','1','SEC')
   + READ (L,*) HW
   + C IS CLUTTER FACTOR (DB)
   + C=10.*ALOG10(HW)
   + DEFAULT VALUES ARE TAKEN TO BE THE SAME AS THOSE USED IN THE
   + WARFARE ENVIRONMENT SIMULATOR PREPARED BY THE NAVAL OCEAN SYSTEMS
   + CENTER IN SAN DIEGO. FOR REVISION SEE MR. BRANDENBURG, AUTOVON
   + 33-2083
   + RL IS SYSTEM LOSS FACTOR (INCLUDES ANTENNA PATTERN (ASSUMED AS
   + 1.5DB) AND ATMOSPHERIC ABSORPTION LOSS (1DB AT 300MHZ AND
   + 3.5DB AT 5000MHZ OVER NAVAL OPERATIONAL RADAR RANGES))

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```

C      IF (FREQ.LT.2.65E9) RL=2.5
C      IF (FREQ.GE.2.65E9) RL=5.0
      RNP IS RECEIVER NOISE FIGURE (DB), MOSTLY THERMAL NOISE.
      RNP=5.5
      RHIN=PL*149.896250
      RRES IS RANGE RESOLUTION
      RRES=RHIN
      RMAX=149896250./PRR
      IF (ISTR.EQ.0) RHNM=1.25*SQRT(HR)+SQRT(HT)
      RHONIZ=RHNM*1829.27
      CALL PRTCHS ('CLRSCRN')
      WRITE (6,30)
      L=5
30     FORMAT (//////, 'DO YOU WANT A PRINTED COPY OF RADAR, TARGET, ',
      + 'DETECTION AND ENVIRONMENT DATA?')
      CALL ANSWER (KP)
      IF (KP.EQ.0) GOTO 100
      CALL PRTCHS ('FILEDEF', '08', 'PRINT', ('', 'RECFM', 'PA', 'BLOCK',
      + '133'))
      WRITE (8,31) RDR$
      FORMAT (8,31) 1A7, 'RADAR', '/'
      WRITE (8,32) PTF
      FORMAT (8,32) 'PEAK TRANSMITTED POWER:', T50, 1PE10.2, ' WATTS')
      WRITE (8,33) GEMMA GAIN: ', T50, F10.2)
      FORMAT (8,33) 'ANTENNA GAIN:', T50, F10.2)
      WRITE (8,34) FREQO
      FORMAT (8,34) 'FREQUENCY:', T50, 1PE10.2, ' HERTZ')
      WRITE (8,35) B
      FORMAT (8,35) 'RECEIVER NOISE FIGURE:', T50, F10.2, ' DB')
      WRITE (8,36) BW
      FORMAT (8,36) 'HORIZONTAL BEAM WIDTH:', T50, F10.2, ' DEGREES')
      WRITE (8,37) BV
      FORMAT (8,37) 'VERTICAL BEAM WIDTH:', T50, F10.2, ' DEGREES')
      WRITE (8,38) ARR
      FORMAT (8,38) 'SCAN RATE:', T50, F10.2, ' RPM')
      WRITE (8,39) PL
      FORMAT (8,39) 'PULSE LENGTH:', T50, F10.2, ' MICROSECONDS')
      WRITE (8,47) PRR
      FORMAT (8,47) 'PULSE REPETITION RATE:', T50, F10.2, ' PPS')
      WRITE (8,40) NP
      FORMAT (8,40) 'PULSES ON TGT PER SWEEP:', T50, I10)
      RHINI=RHIN/1829.27
      WRITE (8,45) RHINI
      FORMAT (8,45) 'MINIMUM RANGE:', T50, F10.2, ' NM')
      WRITE (8,123) LOBE(I,I=1,LOBE)
      FORMAT (8,123) 'ALOBES (', LOBE(S) (DEGREES CW): ', T50, 5F10.2)
      RMA=RHMAX/1829.27
      WRITE (8,46) RMA

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```

46 FORMAT (' MAXIMUM UNAMBIGUOUS RANGE:',T50,F10.2,' NM')
47 WRITE (8,41) TGT$
48 FORMAT (' TARGET:',1A7/' =====')
49 WRITE (8,42) DISP
50 FORMAT (' TARGET MAXIMUM DISPLACEMENT:',T50,F10.2,' KILOTONS')
51 WRITE (8,43) HT
52 FORMAT (' VERTICAL SIZE OF TARGET:',T50,F10.2,' FEET')
53 WRITE (8,44) TCS
54 FORMAT (' TARGET RADAR CROSS-SECTION:',T50,1PE10.2,' SQ METERS')
55 IF ((DISP.LT.2).OR.(DISP.GT.17.)) WRITE (8,12)
56 WRITE (8,50)
57 FORMAT (' ENVIRONMENTAL DATA:'/' =====')
58 WRITE (8,51) HW
59 FORMAT (' SIGNIFICANT WAVE HEIGHT:',T50,F10.2,' FEET')
60 WRITE (8,52) ISTR
61 FORMAT (' DUCTING STRENGTH'/' 0 FOR NO DUCT UP TO 5 FOR ',
62 + ' PERFECT DUCT',T50,1I10)
63 IF ((FREQ.LT.19.E7).OR.(FREQ.GT.12.E9)).AND.(ISTR.GT.0))
64 + WRITE (8,15)
65 IF (ISTR.EQ.0) WRITE (8,53) RHNM
66 FORMAT (' RADAR HORIZON:',T50,F10.2,' NM')
67 IF (ISTR.GT.0) WRITE (8,54)
68 FORMAT (' DUE TO DUCTING, THERE IS NO RADAR HORIZON')
69 DO 80 I=1,NHILLS
70 WRITE (8,63) I,PEAK(I),XMC(I),YMC(I)
71 CONTINUE
72 WRITE (8,60)
73 FORMAT (' DETECTION DATA:'/' =====')
74 WRITE (8,61) IPF$ (IPF)
75 FORMAT (' PROBABILITY OF FALSE ALARM?: ',T50,' 1.',1A3)
76 WRITE (8,62) PDET
77 FORMAT (' PROBABILITY OF DETECTION: ',T50,F10.2)
78 FORMAT (' HILL ',I2,' IS ',F10.2,' METERS TALL, LOCATED AT ',
79 + 2,1X,F6.2)
80 IF (ISTR.EQ.0) RMAX=AMIN1(RMAX,RHORIZ)
81 CALL PRFCHS (' FILEDEF','05','TERM')
82 RETURN
83 END
84 SUBROUTINE INTRO
85 CALL PRFCHS (' CLRSCRN')
86 WRITE (6,1)
87 FORMAT ('////////',T20,'THIS PROJECT FOR JAMES W. MERITT ',
88 + '0',T20,'RADAR MODEL WITH TERRAIN EFFECTS',
89 + '0',T20,'=====')
90 + '0',T20,'THIS IS FOR MASTERS OF OPERATIONS RESEARCH'/'
91 + '0',T20,'THIS IS ADVISOR PROFESSOR HARTMAN'/'
92 + '0',T20,'SECOND READER PROFESSOR FORREST'/'
93 + '0',T20,'SL',5,'SEC')
94 CALL PRFCHS ('CP','SL',5,'SEC')

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CALL PRTCHS ('CLRSCRN')
RETURN
END
SUBROUTINE KOVER(ZO,THACT,SIZET,ZT,S,HTS,ZS,VISFRT)
COMMON /IPRT/ IPRT

C
388 IF (IPRT.GE.10) WRITE(6,388)
   FORMAT(' ***** ENTERED SUBROUTINE KOVER*****')
   IF(S.EQ.0.) GO TO 2000
   IF(HTS.GE.ZS) GO TO 2050
   HEIT=ZO+(HTS-ZO)/S
   EVIST=AMAX1(HEIT,THACT)
   IF(EVIST.GE.ZT) GO TO 2050
   IF(EVIST.LE.ZT-SIZET) RETURN
   VIS=(ZT-EVIST)/SIZET
   IF(VIS.LT.VISFRT) VISFRT=VIS
   RETURN
2000 IF(HTS.LT.ZO) RETURN
2050 VISFRT=0.0
389 IF(IPRT.GE.10) WRITE(6,389)
   FORMAT(' ***** LEAVING SUBROUTINE KOVER*****')
   RETURN
END
SUBROUTINE LAND(RX,RV,X,Y,PAR,SIZEB,A,N,M,IX,IY,XREF,YREF,SP,MASK)
DIMENSION A(N,M)
SUBROUTINE DETERMINES IF LAND IS IN EITHER THE MAIN OR SIDE LOBES
TO DETERMINE IF MASKING WOULD TAKE PLACE.
NEW VARIABLE: MASK=0 IF NO MASKING TAKES PLACE
               MASK=1 IF MASKING TAKES PLACE
COMMON /IPRT/ IPRT
COMMON /HILLS/ XC(100),YC(100),PEAK(100),SX(100),SY(100),RHO(100)
COMMON /HILLS/ SCALE(100),TWOH(100),TWOCL(100),BASE
COMMON /HILLS/ NHILLS
COMMON /COUNTR/ KH,KH1,KV,KM,KGRS,KELL,KINT
COMMON /GRID/ LST(10,10),NHL(10,10),LISTH(450),KHREP(100),KTREP
COMMON /RADAR/ FT,C,W,B,RNF,RL,C,D,RMIN,RMAX,ARES,RRES,LOBE,
+ALOB(5)
DATA PI/3.14159265/,TWOPI/6.283185326/,BIG/57.289952/,S/.017455/
MASK=0
CHECK IF LAND IS ADJACENT TO SEABORNE TARGET
PROCEDURE IS SIMILIAR TO THAT USED IN BEACH
DX=X-RX
DY=Y-RY
IXT=MAX(1,IX-1)
IXB=MIN(M,IX+1)
IYL=MAX(1,IY-1)
IYR=MIN(N,IY+1)
DO 25 I=IXT,IXB

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```

DO 20 J=IYL IYR
IP (A(I,J).LT.SIZEB) GOTO 20
SX1=(SP#FLOAT(I))+XREF
SY1=(SP#FLOAT(J))+YREF
CALL ELEV(SY,SY1,HI,GX,GY)
TILT=(DX#GX+DY#GY)/FAR
IP (TILT.GT.0.02) MASK=1
CONTINUE
IP (MASK.EQ.1) RETURN
GET BEARING TO SUSPECT POINT FROM RADAR
NEXT 4 STEPS ARE TO PREVENT DIVIDE ERROR
IP ((ABS(DX).LE..01).AND.(RY.GE.Y)) TANG=1.5707963
IP ((ABS(DX).LE..01).AND.(RY.GE.Y)) GOTO 100
IP ((ABS(DX).LE..01).AND.(RY.GE.Y)) TANG=4.7123895
IP ((ABS(DX).LE..01).AND.(RY.GE.Y)) GOTO 100
NEXT 9 STEPS ARE TO PREVENT COTAN ERROR
RATIO = DY/DX
IP ((-S.LT.RATIO.AND.RATIO.LT.S).AND.(DX.GT.0)) TANG=0
IP ((-S.LT.RATIO.AND.RATIO.LT.S).AND.(DX.GT.0)) GOTO 100
IP ((-S.LT.RATIO.AND.RATIO.LT.S).AND.(DX.GT.0)) TANG=PI
IP ((-S.LT.RATIO.AND.RATIO.LT.S).AND.(DX.GT.0)) GOTO 100
IP ((RATIO.LT.-BIG.OR.RATIO.GT.BIG).AND.(DY.GT.0)) TANG=PI/2
IP ((RATIO.LT.-BIG.OR.RATIO.GT.BIG).AND.(DY.GT.0)) GOTO 100
IP ((RATIO.LT.-BIG.OR.RATIO.GT.BIG).AND.(DY.GT.0)) TANG=3*PI/2
IP ((RATIO.LT.-BIG.OR.RATIO.GT.BIG).AND.(DY.GT.0)) GOTO 100
TANG=COTAN(RATIO)
TANG=ATAN(RATIO)
IP (DX.LT.0) TANG=TANG+PI
IP ((DY.GT.0).AND.(DY.LT.0)) TANG=TANG+TWOPI
IP (TANG.GT.TWOPI) TANG=TANG-TWOPI
IP (TANG.LT.0) TANG=TANG+TWOPI
CONTINUE
NOW CHECK FOR SIDE LOBE INTERFERENCE
IF (LOBE.LT.1) GOTO 10
DO 5 I=1 LOBE
WAY=TANG+ALOE(I)
IP (WAY.LT.0) WAY=WAY+TWOPI
IP (WAY.GT.TWOPI) WAY=WAY-TWOPI
SY1=RY+PAR#COS(WAY)
SY1=RY-FAR#SIN(WAY)
CALL ELEV(SY1,SY1,HI,GX,GY)
TILT=(DX#GX-DY#GY)/FAR
IP ((HI.GT.SIZEB).AND.(TILT.GT.0.3)) MASK=1
CONTINUE
CONTINUE
RETURN
END

```

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SUBROUTINE LOS (XA, YA, TMACA, TMICA, SIZEA, XB, YB, TMACB, TMICB, SIZEB,
-LATOB, LBTOA, VISFRA, VISFRB, HHW, WRANGE, ISTR)
C***
C*** THIS ROUTINE CALCULATES THE LINE-OF-SIGHT IN TERMS OF A
C*** FRACTION VISIBLE FOR OBSERVER TARGET PAIRS.
C***
C*** XA, YA (XB, YB) X AND Y COORDINATES ON THE FIELD FOR A AND B
C*** TMACA (TMACB) TERRAIN ELEVATION FOR A AND B: ZERO FOR SHIPS.
C*** TMICA (TMICB) HEIGHT OF ANTENNA FOR A 0 FOR B
C*** SIZEA (SIZEB) VERTICAL DIMENSION OF ANTENNA FOR B, VERTICAL
C*** SIZE OF THE SHIP FOR B
C*** LATOB (LBTOA) INDICATOR VARIABLE FOR LOS CALLS
C*** LATOB=1 COMPUTE LOS FROM A TO B YIELDING VISFRB
C*** LATOB=0 DO NOT COMPUTE A TO B
C*** HHW IS THE HEIGHT OF THE OBSTRUCTING HILL
C*** WRANGE IS THE RANGE FROM THE RADAR TO THE OBSTRUCTING HILL
C*** VISFRA (VISFRB) FRACTION OF SIZEA (SIZEB) WHICH CAN BE SEEN BY B (A)
C*** ISTR DUCT INDICATOR. ISTR=0 NO DUCT ISTR=1,2,3,4,5 IMPROVING DUCT

COMMON /IPRT/ IPRT
COMMON /HILLS/ XC(100), YC(100), PEAK(100), SX(100), SY(100), RHO(100)
COMMON /HILLS/ SCALE(100), TWOH(100), TWOHCL(100), BASE
COMMON /HILLS/ NHILLS
COMMON /COUNT/ KH, KHW, KV, KN, KGRS, KELL, KINT
COMMON /GRID/ LST(101), NAL(101), LISTH(450), KHREP(100), KTRER
DIMENSION IGX(100), IGY(100), IEL(100), CSI(100), CS2(100)
DATA NGRID/10/, GSIZE/54878/
CALL RANGE (XA, YA, XB, YB, HOWFAR)
IF (ISTR.EQ.0) CALL ECURVE (HOWFAR, TMACH)
IF (ISTR.EQ.0) THACB=TMACB-TMACH
IF (IPRT.GE.20) WRITE(6,388) XA,YA, XB,YB
FORMAT(' ENTER SUBRTN LOS: FROM',2(2X,F8.0), ' TO',2(2X,F8.0))
VISFRA=1.
VISFRB=1.
XBA=YB-YA
YBA=XB-XA
IF (XBA.EQ.0.) AND. (YBA.EQ.0.) AND. (IPRT.GE.20) WRITE(6,387)
FORMAT(' LEAVE SUBRTN LOS: POSITIONS AT SAME COORDINATES')
IF (XBA.EQ.0.) AND. (YBA.EQ.0.) RETURN
IF (SIZEA+TMICA.LE.0.) GO TO 510
IF (SIZEB+TMICB.LE.0.) GO TO 510
IF (TMICA.LT.0.) VISFRA=1.0+TMICA/SIZEA
IF (TMICB.LT.0.) VISFRB=1.0+TMICB/SIZEB
ZA=TMACA + TMICA + SIZEA
ZB=TMACB + TMICB + SIZEB
KTRER=KTRER+1
ZBA=ZB-ZA
XBASQ=XBA*XBA

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388

387

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YBASQ=YBA*YBA
XYBA=XBA*YBA
THOXBA=2.*XBA
TWOYBA=2.*YBA
C COMPUTE GRID SQUARES CROSSED BY A TO B LINE
NGRSQ=0
95 IF(XBA) 110,95,100
100 XBA=0.1
    ISGX=-1
    XINC=GSIZE/XBA
    GO TO 120
110 ISGX=1
    XINC=-GSIZE/XBA
120 IF(YBA) 140,125,130
125 YBA=0.1
130 ISGY=-1
    YINC=GSIZE/YBA
    GO TO 150
140 ISGY=1
    YINC=-GSIZE/YBA
150 IX=1+IPX(XB/GSIZE)
    IF(IX.GT.NGRID) IX=NGRID
    IY=1+IPY(YB/GSIZE)
    IF(IY.GT.NGRID) IY=NGRID
    XNEXT=GSIZE*(FLOAT{IX}+0.5*{ISGX-1.})
    YNEXT=GSIZE*(FLOAT{IY}+0.5*{ISGY-1.})
    XSTEP=(XB-XNEXT)/XBA
    YSTEP=(YB-YNEXT)/YBA
    NGRSQ=NGRSQ+1
    IGX(NGRSQ)=IX
    IGY(NGRSQ)=IY
    IF((XSTEP.GT.1.) .AND. (YSTEP.GT.1.)) GO TO 200
    IF(XSTEP-YSTEP) 170,180,190
160 IX=IX+ISGX
    XSTEP=XSTEP+XINC
    GO TO 160
170 IY=IY+ISGY
    YSTEP=YSTEP+YINC
    GO TO 160
180 IX=IX+ISGX
    XSTEP=XSTEP+XINC
190 IY=IY+ISGY
    YSTEP=YSTEP+YINC
    GO TO 160
200 KGRS=KGRS+NGRSQ
C GRID SQUARE LIST NOW COMPLETE IN IGX, IGY WITH NGRSQ ENTRIES
C NOW START ON THE HILLS
270 DO 600 K=1,NGRSQ
    IX=IGX(K)
    IY=IGY(K)
    IF(NHL{IX,IY}.EQ.0) GO TO 600

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LS=LST(IX, IY)
LEND=LS+NAL(IX, IY) -1
DO 500 L=LS, LEND
I=LISTH(L)
IP(KHREP(I)-EQ.KTREP) GO TO 500
KHREP(I)=KTREP
C PROCESSING FOR HILL I STARTS HERE
C COMPUTE W=TOP OF THIS HILL ALONG O-T LINE
CY=YBA/SX(I)
DX=YBA/SY(I)
DY={YA-YC(I)}/SX(I)
DY={YA-YC(I)}/SY(I)
FO=THOSCL(I)*{(CX*DX+CY*DY+RHO(I)*(CX*DY+CY*DX))
GO=SCALE(I)*{(CX*CX+CY*CY+THORHO(I)*CX*CY)
IP(GO.EQ.0.) GO TO 500
H=-FO/(2.*GO)
W=RANGE=W*HOWFAR
IP(ABS(W).GT.5.) GO TO 500
FSQ=FO*FO
PO=SCALE(I)*(DX*DX+DY*DY+THORHO(I)*DX*DY)
POWER=EQ.FSQ/(4.*GO)
IP(POWER.LT.-3.) GO TO 500
HHW=PEAK(I)*EXP(POWER)
DROP=0.
IP(ISTR.EQ.0.) CALL ECURVE(WRANGE, DROP)
HHW=HHW-DROP
KHW=KHW+1
IP(HHW.LE.BASE.AND.THACB.EQ.0.) GO TO 500
ZW=ZA+W*ZBA
IP(W.LT.0.) OR.(W.GT.1.) GO TO 300
IP(HHW.GE.ZW) GO TO 510
IP(HHW+CHTMAX.LT.AMIN1(ZA-SIZEA, ZB-SIZEB)) GO TO 500
C IF WE GET TO HERE THEN NEED TO FIND LOWEST SIGHT LINE OVER HILL
C NEWTON ITERATION A TO B GIVING VISFEB
IP(LATOB.EQ.0) GO TO 400
KV=KV+1
V=W
HHV=HHW
NCT=0
PV=FO*V
THOGV=2.*GO*V
PCNV=ZA+HHV*(THOGV*V+V-1.)
KN=KN+1
FACTOR=(THOGV*THOGV+2.*(GO+THOGV*FO)+FSQ)
DPCNV=HHV*V*FACTOR
IP(ABS(DPCNV).LT.1.E-10) GO TO 350
V=V-PCNV/DPCNV

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PV=PO*V
TWOGV=2.*GQ*V
POWER = EQ+PV+GQ*V*V
IF (POWER.LT.-3.) GO TO 400
HHV=PEAK(I)*EXP(POWER)
DROP=0.
IF (ISTR.EQ.0.) CALL ECURVE (WRANGE,DROP)
HHV=HHV-DROP
DHHV=HHV*(FQ+TWOGV)
ELV=ZA+DHHV*V
IF (ABS(HHV-ELV) .LT.1.) GO TO 350
NCT=NCT+1
IF (NCT.LT.10) GO TO 330
IF (V.LT.0.) OR (V.GT.1.)) GO TO 400
HTV=HHV
ZV=ZA+V*ZEA
CALL KOVER(ZA,THACB,SIZEB,ZB,V,HTV,ZV,VISFEB)
IF (VISPRB.LE.0.) GO TO 510
C NEWTON ITERATION B TO A GIVING VISFRA
IF (ABS(V).GT.5.) GO TO 400
IF (LBTOA.EQ.0) GO TO 500
KV=KV+1
V=N
VM1=V-1.
HHV=HHV
NCT=0
PV=PO*V
TWOGV=2.*GQ*V
PCNV=ZB+HHV*((FQ+TWOGV)*VM1-1.)
KN=KN+1
FACTOR=(TWOGV*TWOGV+2.*(GQ+TWOGV*FQ)+FSQ)
DFCNV=HHV*VM1*FACTOR
IF (ABS(DFCNV) .LT.1.E-10) GO TO 450
V=V-PCNV/DFCNV
IF (ABS(V).GT.5.) GO TO 500
VM1=V-1.
PV=PO*V
TWOGV=2.*GQ*V
POWER = EQ+PV+GQ*V*V
IF (POWER.LT.-3.) GO TO 500
HHV=PEAK(I)*EXP(POWER)
DROP=0.
IF (ISTR.EQ.0.) CALL ECURVE (WRANGE,DROP)
HHV=HHV-DROP
DHHV=HHV*(FQ+TWOGV)
ELV=ZB+DHHV*VM1
IF (ABS(HHV-ELV) .LT.1.) GO TO 450
NCT=NCT+1

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450      IF (NCT.LT.10) GO TO 430
      IF (V.LT.0.) OR (V.GT.1.) GO TO 500
      HTV=HHV
      ZV=ZA+V*ZBA
      S=-VM1
500      CALL KOVER(ZB,THACA,SIZEA,ZA,S,HTV,ZV,VISFRA)
600      IF (VISFRA.LE.0.) GO TO 510
      CONTINUE
386      IF (IPRT:GE.20) WRITE(6,386) VISFRA,VISFRB
      FORMAT(' LEAVE SUBRTN LOS: VISFRA = ',F10.8,' VISFRB = ',F10.8)
510      VISFRA=0.
      VISFRB=0.
389      IF (IPRT:GE.10) WRITE(6,389)
      FORMAT(' LEAVE SUBRTN LOS: NO LINE OF SIGHT EXISTS ')
      RETURN
      END
      SUBROUTINE MOD (SE,TCS,ISTR,HR,SIZEA,SIZEB,RX,RY,TMICA)
      COMMON /HILLS/ XC(100),YC(100),PEAK(100),SX(100),SY(100),RHO(100)
      COMMON /HILLS/ SCALE(100),THORHO(100),TWOCL(100),BASE
      COMMON /HILLS/ NHILLS
      COMMON /RADAR/ PT,G,W,B,RNF,RL,C,D,RMIN,RHAX,ARES,RRES,LOBE,
      +ALOBE(5)
      COMMON /RDR/RDR$,TGTS$,PRT,BW,BV,FREQ,SW,ARM,PL,DISP,HT,HM,PDET,PTR
      COMMON /HILL/ YMC(100),YMC(100)
      REAL*8 RDR$,TGTS$,IPFS(4),E-4,E-6,E-8,E-10
      ROUTINE IS USED TO MODIFY THE RADAR, TARGET ENVIRONMENT, AND
      DETECTION DATA EARLIER INPUT VIA THE INPUT ROUTINE TO ALLOW
      RE-RUNNING THE PROGRAM WITH VARYING PARAMETERS.
      FOR AN EXPLANATION OF THE VARIABLES, SEE SUBROUTINE INPUT
      CALL FRCHS ('CLNSCRN')
      WRITE (6,5)
      FORMAT (
      + 1- NAME OF RADAR: T40, 11- ANTENNA HEIGHT: //
      + 2- PEAK POWER: T40, 12- RADAR COORDINATES, //
      + 3- BANDWIDTH: T40, 13- TARGET NAME: //
      + 4- PRT: T40, 14- TARGET SIZE: //
      + 5- HORIZONTAL BEAM WIDTH: T40, 15- TARGET DISPLACEMENT: //
      + 6- VERTICAL BEAM WIDTH: T40, 16- DUCTING STRENGTH: //
      + 7- SECTOR SIZE: T40, 17- PROBABILITY OF FAILURE: //
      + 8- SCAN RATE: T40, 18- PROBABILITY OF DETECTION: //
      + 9- PULSE LENGTH: T40, 19- WAVE HEIGHT: //
      + 10- FREQUENCY: T40, 20- END OF CHANGES: //
      + 1- ENTER NUMBER CORRESPONDING TO DESIRED CHANGE: ')
      READ (5,*) K
      CALL FRCHS ('CLNSCRN')
      GOTO (101,102,103,104,105,106,107,108,109,110,111,112,

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C C C C 1 5

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101      +113,114,115,116,117,118,119,120).K
201      WRITE (6,201)
301      FORMAT (' NAME OF RADAR SYSTEM')
102      READ (5,301) RDR$
202      FORMAT (1A7)
103      GOTO 1
203      WRITE (6,202)
303      FORMAT (' PEAK TRANSMITTED POWER (WATTS)')
104      READ (5,*) PTR
204      PT=10.*ALOG10(PTR)
304      GOTO 1
105      WRITE (203)
205      FORMAT (' RECEIVER IF BANDWIDTH (MHZ)')
305      READ (5,*) B
206      B=ALOG10(B)
306      GOTO 1
107      WRITE (6,204)
207      FORMAT (' PULSE REPETITION RATE (PPS)')
307      READ (5,*) PRR
208      RMAX=149896250./PRR
308      GOTO 1
109      WRITE (205)
209      FORMAT (' HORIZONTAL BEAM WIDTH (DEGREES)')
309      READ (5,*) BW
210      ARES=BW
309      GOTO 1
110      WRITE (6,206)
210      FORMAT (' VERTICAL BEAM WIDTH (DEGREES)')
310      READ (5,*) BV
211      GOTO 1
111      WRITE (6,207)
211      FORMAT (' ANGULAR WIDTH OF SWEPH SECTOR (DEGREES)')
311      READ (5,*) SW
212      GOTO 1
112      WRITE (6,208)
212      FORMAT (' SCAN RATE (SPH)')
312      READ (5,*) ARR
213      GOTO 1
113      WRITE (6,209)
213      FORMAT (' PULSE LENGTH (MICROSECONDS)')
313      READ (5,*) PL
214      RMIN=149.89625*PL
314      RRES=RMIN
314      GOTO 1
114      WRITE (6,210)
214      FORMAT (' FREQUENCY (HERTZ)')
314      READ (5,*) FREQ
215      W=ALOG10(29979250000./FREQ)

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111 IF (PREQ.LT.2.65E9) RL=2.5
211 IF (PREQ.GE.2.65E9) RL=5.0
    WRITE (6,211)
    FORMAT (' ANTENNA HEIGHT (FEET)')
    READ (5,*) HR
    THICA=.3048781*HR
    GOTO 1
212 WRITE (6,212)
    FORMAT (' S-E COORDINATES OF RADAR (NM)')
    READ (5,*) AX,RY
    RX=RX*1829.27
    RY=RY*1829.27
    GOTO 1
213 WRITE (6,213)
    FORMAT (' TARGET NAME')
    READ (5,301) TGT$
    GOTO 1
214 WRITE (6,214)
    FORMAT (' SIZE OF TARGET (FEET)')
    READ (5,*) HT
    SIZEB=HT*.3048781
    GOTO 1
215 WRITE (6,215)
    FORMAT (' TARGET MAXIMUM DISPLACEMENT (KILOTONS)')
    READ (5,*) DISP
    IF (DISP.LT.2) .OR. (DISP.GT.17.1) WRITE (6,315)
    FORMAT (' WARNING: TARGET CROSS SECTION MAY BE IN ERROR')
    GOTO 1
216 WRITE (6,216)
    FORMAT (' DUCTING STRENGTH: 0 TO 5')
    READ (5,*) ISTR
    IF (ISTR.LT.0) .OR. (ISTR.GT.5) GOTO 116
    IF (ISTR.EQ.0) D=1.0
    IF (ISTR.EQ.1) D=1.35
    IF (ISTR.EQ.2) D=1.2
    IF (ISTR.EQ.3) D=1.11
    IF (ISTR.EQ.4) D=1.05
    IF (ISTR.EQ.5) D=1.0
    GOTO 1
217 WRITE (6,217)
    FORMAT (' PROBABILITY OF FAILURE:/' 1=E-4/' 2=E-6/' 3=E-8/'
    + 4=E-10')
    READ (5,*) IPP
    GOTO 1
218 WRITE (6,218)
    FORMAT (' SINGLE SWEEP PROBABILITY OF DETECTION')

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318 READ (5,*) PDET
    IF ((PDET.GT.0.).AND.(PDET.LT.1.)) GOTO 1
    WRITE (6,318)
    FORMAT (' PROBABILITIES ARE BETWEEN ZERO AND ONE. REENTER. ')
119 GOTO 118
219 WRITE (6,219)
    FORMAT (' SIGNIFICANT WAVE HEIGHT (FEET) ')
    READ (5,*) HW
    C=10.*ALOG10(HW)
120 GOTO 1
    CONTINUE
    G=ALOG10(41252.962/(BW*BV))
    SIZEA=29792500/(BV*PFRQ)
    NP=INT((60.*PFRQ*BW)/(SM*ARR))
    TCS=52.*SQRT(PFRQ/1.E6)*DISP*1.5
    CALL PD2SE(SE,NP,PP,PDET)
    IF (ISTR.EQ.0) RHNM=1.25*(SQRT(HR)+SQRT(HT))
    RHOMZ=1829.27*RHNM
    WRITE (6,30)
30  FORMAT ('////////// DO YOU WANT A PRINTED COPY OF RADAR, TARGET, ',
    + ' DETECTION AND ENVIRONMENT DATA? ')
    CALL ANSWER (KP)
    IF (KP.EQ.0) GOTO 100
    CALL PRTCHS ('FILEDEF','08','PRINT','(','RECPR','FA','BLOCK',
    + '133')
1000 WRITE (8,1000)
    FORMAT ('1PROJECT BEING RUN WITH REVISED DATA'
    + '=====')
    WRITE (8,31) RDR$
    WRITE (8,32) PTR
    FORMAT (' PEAK TRANSMITTED POWER:',T50,1PE10.2,' WATTS')
31  WRITE (8,33) G
    WRITE (8,34) ANTENNA GAIN:',T50,F10.2)
32  FORMAT (' ANTENNA GAIN:',T50,1PE10.2,' HERTZ')
    WRITE (8,35) B
    WRITE (8,36) RECEIVER NOISE FIGURE:',T50,F10.2,' DB')
33  FORMAT (' RECEIVER NOISE FIGURE:',T50,F10.2,' DB')
    WRITE (8,37) BW
    WRITE (8,38) HORIZONTAL BEAM WIDTH:',T50,F10.2,' DEGREES')
34  FORMAT (' HORIZONTAL BEAM WIDTH:',T50,F10.2,' DEGREES')
    WRITE (8,39) ARR
    WRITE (8,40) VERTICAL BEAM WIDTH:',T50,F10.2,' DEGREES')
35  FORMAT (' VERTICAL BEAM WIDTH:',T50,F10.2,' DEGREES')
    WRITE (8,41) RPM
    WRITE (8,42) SCAN RATE:',T50,F10.2,' RPM')
36  FORMAT (' SCAN RATE:',T50,F10.2,' RPM')
    WRITE (8,43) PL
    WRITE (8,44) PULSE LENGTH:',T50,F10.2,' MICROSECONDS')
37  FORMAT (' PULSE LENGTH:',T50,F10.2,' MICROSECONDS')
    WRITE (8,45) PPR
    WRITE (8,46) PULSE REPETITION RATE:',T50,F10.2,' PPS')
38  FORMAT (' PULSE REPETITION RATE:',T50,F10.2,' PPS')
39  WRITE (8,47) PPR
47  FORMAT (' PULSE REPETITION RATE:',T50,F10.2,' PPS')

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40 WRITE (8,40) NP
   FORMAT (' PULSES ON TGT PER SWEEP',T50,I10)
   RHINI=RHIN/1829.27
45 WRITE (8,45) RHINI
   FORMAT (' MINIMUM RANGE:',T50,F10.2,' NM')
   RMA=RMAX/1829.27
46 WRITE (8,46) RMA
   FORMAT (' MAXIMUM UNAMBIGUOUS RANGE:',T50,F10.2,' NM')
41 WRITE (8,41) TGT$
   FORMAT (' TARGET:',1A7/' =====')
42 WRITE (8,42) DISP
   FORMAT (' TARGET MAXIMUM DISPLACEMENT:',T50,F10.2,' KILOTONS')
43 WRITE (8,43) HT
   FORMAT (' VERTICAL SIZE OF TARGET:',T50,F10.2,' FEET')
44 WRITE (8,44) TCS
   FORMAT (' TARGET RADAR CROSS-SECTION:',T50,F10.2,' SQ METERS')
   IF ((DISP.LT.2).OR.(DISP.GT.17.)) WRITE (8,315)
45 WRITE (8,50)
   FORMAT (' ENVIRONMENTAL DATA:'/' =====')
46 WRITE (8,51) HM
   FORMAT (' SIGNIFICANT WAVE HEIGHT:',T50,F10.2,' FEET')
47 WRITE (8,52) ISTR
   FORMAT (' DUCTING STRENGTH/' 0 FOR NO DUCT UP TO 5 FOR ',
+PERPECT DUCT:T50,I10)
48 IF ((FREQ.LT.19.E7).OR.(FREQ.GT.12.E9)).AND.(ISTR.GT.0))
+WRITE (8,15)
15 FORMAT (' WARNING: DUCTING MAY BE IN ERROR')
   IF (ISTR.EQ.0) WRITE (8,53) RHNM
53 FORMAT (' RADAR HORIZON:',T50,F10.2,' NM')
   IF (ISTR.GT.0) WRITE (8,54)
54 FORMAT (' DUE TO DUCTING, THERE IS NO RADAR HORIZON')
   DO 80 I=1,NHILLS
   WRITE (8,63) I,PEAK(I),XMC(I),YMC(I)
80 CONTINUE
   WRITE (8,60)
60 FORMAT (' DETECTION DATA:'/' =====')
   WRITE (8,61) IPF$ (IPF)
61 FORMAT (' PROBABILITY OF FAILURE ',T50,' 1.',1A3)
   WRITE (8,62) PDET
62 FORMAT (' PROBABILITY OF DETECTION ',T50,F10.2)
63 FORMAT (' HILL ',I2,' IS ',F10.2,' METERS TALL, LOCATED AT ',
+2(IY,P6.2))
   IF (ISTR.EQ.0) RMAX=AHINI(RMAX,RHORIZ)
   CALL PRTCMS ('FILEDEF',05,'TERM')
   RETURN
END
SUBROUTINE OBGAIN (FAR,HM,WRANGE,THICA,SIZEB,OBGN)
COMMON /RADAR/ET,G,W,B,RNF,RL,C,D,RHIN,RMAX,ARES,RRES,LOBE,

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+ALOE(5)
DATA TWOPI/6.2831853/
ROUTINE CALCULATES THE "OBSTACLE GAIN" CREATED BY THE RADIO WAVES
BEING DEFRACED OVER THE HILL TOPS. A "KNIFE EDGE" OBSTACLE IS
ASSUMED, AND THE CALCULATIONS ARE PERFORMED USING THE FORMULAS
GIVEN BY ARNOLD PICQUENARD'S BOOK "RADIO WAVE PROPAGATION",
SECTION 8.3.2.3 PAGES 294 THROUGH 296.
VARIABLES ARE:
H1 ELEVATION OF THE RADAR
H0 ELEVATION OF THE HILL
H2 ELEVATION OF THE TARGET
D1 RANGE FROM THE RADAR TO THE HILL
D2 RANGE FROM THE HILL TO THE TARGET

RLAMDA=100.*EXP(W)
H0=HW
D1=WRANGE
D2=PAR-D1
H1=TWICA
H2=SIZEB
H1P=H0-TWICA
H2P=H0-H2
CHECK TO SEE IF THE HILL IS THE HIGHEST OF THE THREE
IF IT ISN'T USE AN OBSTRUCTION VALUE INDICATING AT THE EDGE
IF (H0.GT.H1.AND.H0.GT.H2) GOTO 50
OBGN=.90309
RETURN
V0=H0*SQRT((2./RLAMDA)*((1./D1)+(1./D2)))
OBGN=1.+20.*ALOG10(V0)-20.*ALOG10(SIN((TWOPI*H1*H1P)/(RLAMDA*D2)))
-20.*ALOG10(SIN((TWOPI*H2*H2P)/(RLAMDA*D1)))
RETURN
END
REAL FUNCTION PARSS(A$,LA,IDIM,IER)
*****
A$ IS A REAL*8 CHARACTER STRING TO BE SEARCHED FOR THE
OCCURRENCE OF THE 1ST NON-LEADING BLANK. A$ IS THEN SPLIT
INTO TWO SUBSTRINGS, THE LEADING TOKEN (FIRST WORD) IS
RETURNED AS THE FUNCTION VALUE AND THE REMAINDER IS PLACED
BACK IN A$.
LA IS AN INTEGER VARIABLE WHOSE VALUE IS THE NUMBER OF
CHARACTERS IN A$ THAT ARE TO BE PARSED. ON RETURN, LA IS
THE NUMBER OF NON-BLANK CHARACTERS REMAINING IN A$ AFTER THE
REMOVAL OF THE FIRST WORD.
IDIM IS AN INTEGER VARIABLE OR CONSTANT WHOSE VALUE IS THE
SIZE OF THE STRING ARRAY TO BE PARSED EXACTLY AS DIMENSIONED
IN THE CALLING PROGRAM.
*****

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C** IER IS AN INTEGER ERROR RETURN CODE EQUAL TO -1 IF LA IS
C** .GT. 80 .OR. .GT. 8*IDIM .OR. .LT. 0.
C**
C** AN ATTEMPT TO PARSE A NULL STRING WILL RESULT IN A SPECIAL
C** CHARACTER BEING PLACED IN THE IST POSITION OF A$. A SUBSEQUENT
C** ATTEMPT TO REPARSE THIS STRING WILL RESULT IN A FATAL ERROR.
C** THIS FEATURE IS INTENDED TO PREVENT UNCONTROLLED LOOPING OF THE
C** PARSE FUNCTION ON A NULL STRING. THE SPECIAL CHARACTER USED
C** IS KNOWN ONLY TO THIS ROUTINE AND MAY BE USED AS A REGULAR
C** CHARACTER FOR IN ANY STRING OF LENGTH GREATER THAN ZERO.
C**
C** PAR$$ AND THE RESULT OF THE FUNCTION CALL TO PAR$$ MUST BOTH
C** BE TYPED REAL*8 IN THE CALLING PROGRAM.
C** ROUTINE WRITTEN BY MARK L. YOUNT
C** USED IN ROUTINE SELECT TO PICK FILE FOR TERRAINE DATA
C**
C** IMPLICIT INTEGER(A-Z)
C** REAL*8 PAR$$
C** COMMON/FILES/ IPRT,ICONIN,ICNOUT,IPRINT,IDSK(30)
C** REAL*8 A$(IDIM),AA$(10),B$,BLANK8,
C** LOGICAL*1 C$(80),D$(8),TEST1(2)
C** LOGICAL*1 BLANK1,
C** LOGICAL*1 HALT,
C** INTEGER*4 FUNC$,
C** INTEGER*2 TEST2,BLANK2,
C** EQUIVALENCE(C$(1),AA$(1)),(B$(1),B$),(TEST1(1),TEST2)
C** DO 1 I=1, IDIM
C**   AA$(I) = A$(I)
C**   AS(I) = BLANK8
C** CONTINUE
C** IF(IPRT.GE.10) WRITE(ICNOUT,200) LA,(C$(I),I=1,LA)
C** IF(ORMAT(TRACE,I3,PAR$$,B$,BLANK8)
C** B$ = BLANK8
C** IF(LA.GT.80.OR.LA.GT.8*IDIM.OR.LA.LT.0) GOTO 6000
C** IF(CHECK TO SEE IF INPUT STRING IS NULL
C** IF(LA.LE.0) GOTO 5
C** IF(IPRT.GE.20) WRITE(ICNOUT,204)
C** IF(ORMAT( ATTEMPTED TO PARSE A NULL STRING. '))
C** TEST2 = BLANK2
C** TEST1(1) = C$(1)
C** IF(TEST2.EQ.HALT2) GOTO 6005
C** C$(1)=HALT
C** PAR$$=B$
C** LA=0
C** RETURN
C** TRIM THE INPUT STRING OF LEADING BLANKS
C** IH=0

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```

DO 10 I=1,LA
TEST2 = BLANK2
TEST1(1) = C$(I)
IF (TEST2.NE.BLANK2) GOTO 15
IM=IM+1
CONTINUE
IP(IM.EQ.0) GOTO 25
IF (IPRT.GE.20) WRITE(ICNOUT,201) IM
FORMAT(' FOUND',I3,' LEADING BLANKS IN INPUT STRING')
IP(IM.LT.LA) GOTO 20
LA=0
PARS$=E$
IF (IPRT.GE.20) WRITE(ICNOUT,202)
FORMAT(' FOUND INPUT STRING IS ALL BLANKS')
RETURN
LEPT=LA-IM
DO 23 I=1,LEPT
C$(I)=C$(I+IM)
CONTINUE
LA=LEPT
LOCATE THE FIRST NON-LEADING BLANK IN A$ (THEREBY DETERMINE LB)
LB=0
DO 30 I=1,LA
TEST2 = BLANK2
TEST1(1) = C$(I)
IF (TEST2.EQ.BLANK2) GOTO 35
LB=LB+1
CONTINUE
CONSTRUCT TOKEN
DO 45 I=1,LB
IF (I.GT. 8) GOTO 46
D$(I)=C$(I)
CONTINUE
PARS$ = B$
IF (IPRT.GE.20) WRITE(ICNOUT,205) LB,B$
FORMAT(' PARS$ FOUND TOKEN',I3,' A8)
REMOVE TOKEN FROM FRONT OF INPUT STRING
LEPT=LA-LB-1
IF (LEPT.GT.0) GOTO 50
LA=0
GOTO 75
DO 55 I=1,LEPT
C$(I)=C$(I+LB+1)
CONTINUE
LA=LEPT
DO 56 I=1,IDIM

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I=15
IF {NP.LT.900} I=14
IF {NP.LT.700} I=13
IF {NP.LT.500} I=12
IF {NP.LT.300} I=11
IF {NP.LT.150} I=NP/10
IF {I.LT.1} I=1
RMU=PF(I,IPF)
USING BLAKE'S RESULTS OF NEL RPT 6930, AS IN W.E.S.
CALL MDNRIS (PDET,Z,IER)
SE=7.*Z+RMU
RETURN
END
SUBROUTINE RANGE (X1,Y1,X2,Y2,RANGE)
ROUTINE FINDS RANGE BETWEEN (X1,Y1) AND (X2,Y2) IN A PLANE
RANGE=SQRT((X2-X1)**2+(Y2-Y1)**2)
RETURN
END
SUBROUTINE RMAP(A,N,M,SPNM)
DIMENSION A(N,M),BV(2)
REAL*8 CR
RMAP IS A VERSION OF THAP MODIFIED TO ALLOW THE USE OF SPECIAL
SYMBOLS. THAP HAS BEEN SUBMITTED FOR THE NONIMSL LIBRARY AT NPS
ROUTINE INTERACTIVELY TAKES AN ARRAY AND PREPARES A CONTOUR MAP
FOR THE VICINITY OF A GIVEN POINT. THE OUTPUT IS ON A TERMINAL
OR ON THE PRINTER, AT THE OPTION OF THE USER, INTERACTIVELY
TAKING INPUT FROM A KEYBOARD.
PASSED ARGUMENTS: N AND M ARE ITS DIMENSION
SPNM IS THE NUMBER OF NAUTICAL MILES BETWEEN
SAMPLED POINTS
OTHER ARGUMENTS ARE REQUESTED AT THE TERMINAL
LARGE AMOUNTS OF VIRTUAL STORAGE ARE REQUIRED FOR LARGE ARRAYS
UP TO 1M MAY BE REQUIRED FOR A 400X400 ARRAY.
PROGRAM IS A MODIFIED VERSION OF PROFESSOR GILLES CANTIN'S
JAMES W. MERITT, LT USN
CALL PREMAP (A,N,M,SCF,BV,SPNM)
WRITE (6,10)
FORMAT (1 SCREEN DISPLAY DESIRED?)
CALL ANSWER (K)
IF (K.NE.1) GOTO 20
CONTINUE
CALL PSTMAP (A,N,M,SPNM)
WRITE (6,1)
FORMAT (1 ANOTHER?)
CALL ANSWER (K)
IF (K.EQ.1) GOTO 100

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20 WRITE (6,2)
2  FORMAT ('PRINTED VERSION OF ARRAY DESIRED?')
  CALL ANSWER (KL)
  IF (KL.EQ.1) CALL PRTHAP (A,N,M,BV,SCF,SPNM)
  DO 60 I=1,N
  DO 61 J=1,M
61 IF (A(I,J).GE.0.0) A(I,J)=A(I,J)/SCF
60 CONTINUE
  RETURN
END
SUBROUTINE PREMAP(A,N,M,SCF,BV,SPNM)
  ROUTINE PREPARES THE ARRAY FOR PLOTTING AND PRINTS THE
  SCALE ON THE TERMINAL.
  DIMENSION BV(21),A(N,M)
  CALL PRTHMS {'CLSCRN'}
  AMIN=0.0
  AMAX=-1.E+70
  DO 11 I=1,N
  DO 10 J=1,M
10 AMAX=AMAX1(A(I,J))
11 CONTINUE
  RGE=AMAX
  IF (ABS(RGE)-1.0E-10) 12,12,13
12 WRITE(6,1000) SPNM
  WRITE(6,1400) RGE,AMAX,AMIN
1000 FORMAT ('THERE ARE ',F6.2,'NM BETWEEN POINTS')
1400 FORMAT ('//5X,13H THE RANGE IS,E15.6,/,5X,13H
15X,13H MINIMUM IS,E15.6,/,
16X,13H MAXIMUM IS,E15.6,/,
17X,13H')
  SCF=1.
  RETURN
13 CONTINUE
  SCF=40./AMAX
  DO 21 I=1,N
  DO 20 J=1,M
20 IF (A(I,J).GE.0.0) A(I,J)=SCF*A(I,J)
21 CONTINUE
  DO 30 I=1,21
  AI=FLOAT(I-1)
  BV(I)=(2.*AI/SCF)+AMIN
30 WRITE(6,1050) SPNM
  WRITE(6,1300) BV(1),BV(21)
  WRITE(6,1100) BV(2),BV(3),BV(4),BV(5),BV(6),
  WRITE(6,1200) BV(7),BV(8),BV(9),BV(10),BV(11),
  WRITE(6,1210) BV(12),BV(13),BV(14),BV(15),BV(16),
  WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)
  WRITE(6,4000)
4000 FORMAT ('5X,'$=RADAR
1050 FORMAT ('//1 THERE ARE ',F6.2,'NM BETWEEN POINTS')

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1100 FORMAT (5X,3H A=,F8.3,3X,3H B=,F8.3,3X,3H C=,F8.3,3X,3H D=,F8.3,
13X,3H E=,F8.3)
1200 FORMAT (5X,3H F=,F8.3,3X,3H G=,F8.3,3X,3H H=,F8.3,3X,3H I=,F8.3,
13X,3H J=,F8.3)
1210 FORMAT (5X,3H Q=,F8.3,3X,3H R=,F8.3,3X,3H S=,F8.3,3X,3H T=,F8.3,
13X,3H U=,F8.3)
1220 FORMAT (5X,3H V=,F8.3,3X,3H W=,F8.3,3X,3H X=,F8.3,3X,3H Y=,F8.3,
13X,3H Z=,F8.3)
1300 FORMAT (5X,3H O=,F10.6,5X,7H RANGE(,E15.6,5X,E15.6,2H ))
2000 FORMAT (2X,115A1)
RETURN
END
C
SUBROUTINE PSTMAP(A,N,M,SFNM)
SUBROUTINE PLOTS THE CONTOUR MAP ON THE SCREEN
DIMENSION LINE(80),ISYMB(42),HBV(21),A(N,M),HC(1H,1HD,1H,1HE
DATA ISYMB/1H,1H,1H,1HA,1H,1HB,1H,1HC,1H,1HD,1H,1HE,1H,1HF,1H,1HG,1H,1
1H,1HP,1H,1HQ,1H,1HR,1H,1HS,
2H,1HT,1H,1HU,1H,1HV,1H,1HW,1H,1HX,1H,1HY,1H,1HZ,
DATA IBLK/1H,1H,1HIDE/1H,1H,1HSHIP/1H,1H,1HCOAST/1H,1H,1H//
WRITE (6,1)
FORMAT (1)
* REFERENCE POINT
READ (5,*) RX,RY
IX=INT(RX/SFNM)
IY=INT(RY/SFNM)
IX=MAX(IY,1)
IY=MAX(IX,N)
IX=MIN(IX,M)
IY=MIN(IY,M)
IXT=IX-10
IYL=IY-10
IXT=IX-40
IYL=IY-40
IF (IXT.LE.0) IXT=1
IF (IYL.LE.0) IYL=1
CALL PRTCMS ('CIRSCRN')
IXB=MIN(N,IXT+20)
IYB=MIN(M,IYL+80)
WRITE (6,200) RX,RY
FORMAT (1) PLOT CENTERED ON ',F6.2,'NM SOUTH AND ',F6.2,'NM EAST')
DO 50 K=IXT,IYB
DO 40 J=IYL,IYR
AJ=A(K,J)+2.50001
JK=J-IYL+1
JJ=INT(AJ)
JK=J-IYL+1
JJ=J-IYL+1
IF (JJ.GT.0) LINE(JK)=ISYMB(JJ)
IF (JJ.EQ.0) LINE(JK)=IHIDE
IF (JJ.EQ.-1) LINE(JK)=MSHIP
IF (JJ.EQ.-2) LINE(JK)=KOAST
40 CONTINUE

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46 CONTINUE
WRITE(6,2000) (LINE(L),L=1,80)
DO 45 I=1,80
LINE(I)=IBLK
50 CONTINUE
2000 FORMAT(' ',80A1)
RETURN
END
SUBROUTINE PRTHMAP(A,N,M,BV,SCF,SFNM)
SUBROUTINE PLOTS CONTOUR MAP ON PRINTER. IF ARRAY IS OVER
100 CHARACTERS WIDE, IT IS PLOTTED IN STRIPS.
DIMENSION LINE(100),ISYMB(42),BV(21),A(N,M)
DATA ISYMB/1H 1AG,1H 1AH,1H 1AI,1H 1AJ,1H 1AQ,1H 1AR,1H 1AS,
1H 1AT,1H 1AU,1H 1AV,1H 1AW,1H 1AX,1H 1AY,1H 1AZ,
2H 1A IBLK/1H /,1H HIDE/1H #,1H MSHIP/1H $,1H KOAST/1H //,
DATA A,BLK/1H /,1H HIDE/1H #,1H MSHIP/1H $,1H KOAST/1H //,
CALL FRTCMS ('FILEDEF',.08,.PRINT,('RECPRM',.FA,.BLOCK',
+.133.)
WRITE(8,1)
FORMAT(1)CONTOUR MAP OF ENTIRE DATA SET: '///)
WRITE(8,1050) SFNM
WRITE(8,1300) BV(1),BV(2),BV(3),BV(4),BV(5),BV(8),
WRITE(8,1100) BV(2),BV(3),BV(4),BV(5),BV(8),
WRITE(8,1200) BV(7),BV(8),BV(9),BV(10),BV(11),
WRITE(8,1210) BV(12),BV(13),BV(14),BV(15),BV(16),
WRITE(8,1220) BV(17),BV(18),BV(19),BV(20),BV(21)
WRITE(8,4000)
WRITE(5X,1) $=RADAR *$=MASKED
FORMAT(5X,1) $=RADAR *$=MASKED
1050 FORMAT(5X,1) $=RADAR *$=MASKED
1100 FORMAT(5X,3H A=,F8.3,3X,3H B=,F8.3,3X,3H C=,F8.3,
13X,3H E=,F8.3)
1200 FORMAT(5X,3H F=,F8.3,3X,3H G=,F8.3,3X,3H H=,F8.3,3X,3H I=,F8.3,
13X,3H J=,F8.3)
1210 FORMAT(5X,3H Q=,F8.3,3X,3H R=,F8.3,3X,3H S=,F8.3,3X,3H T=,F8.3,
13X,3H U=,F8.3)
1220 FORMAT(5X,3H V=,F8.3,3X,3H W=,F8.3,3X,3H X=,F8.3,3X,3H Y=,F8.3,
13X,3H Z=,F8.3)
1300 FORMAT(5X,3H O=,F10.6,5X,7H RANGE(,E15.6,5X,E15.6,2H ))
IYL=1
IYR=100
WRITE(8,200) IYL,IYR
200 FORMAT(1)PLOT FROM 'I3,' TO ',I3)
3000 FORMAT(8,3000)
WRITE(8,3000)
FORMAT(8,3000)
DO 50 K=1,N
DO 40 J=1,L,IYR
JK=J-IYL+1
5 6 1 7 2 8 3 9 4 0

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AJ=A(K,J)+2.50001
JJ=INT(AJ)
IF (JJ.GT.0) LINE(JK)=ISYMB(JJ)
IF (JJ.EQ.0) LINE(JK)=IHIDE
IF (JJ.EQ.-1) LINE(JK)=MSHIP
IF (JJ.EQ.-2) LINE(JK)=KOAST
CONTINUE
40 CONTINUE
46 WRITE(8,2000) K,(LINE(L),L=1,100)
DO 45 I=1,100
45 LINE(I)=IBLK
CONTINUE
50 IYL=IYR+1
IYR=MIN(IYL+100,M)
IF (IYL.LT.IYR) GOTO 1000
2000 FORMAT(6,15,' ',100A1)
3001 WRITE(6,3001)
FORNAT (6, CONTOUR MAP OF ARRAY SENT TO PRINTER')
RETURN
END
SUBROUTINE SELECT
REAL*8 FILES(3), PNAME$, FTYPE$, FMODE$, FILES$(3),
* PARS$, A1,A1, SEC, FILE/,67,/, FNUM$
ROUTINE ADAPTED FROM ONE PROVIDED BY MARK L. YOUNT, USED IN
CONJUNCTION WITH PARS TO DEFINE DATA FILES
REWIND 7
WRITE(6,205)
205 FORMAT(6X,'ENTER A FILE IDENTIFICATION <FN FT FH>')
100 READ(5,100) FILES
FORNAT(3A8)
LA = 24
PNAME$ = PARS$(FILES$,LA,3,IER)
IF (IER.NE.0) STOP
FTYPE$ = PARS$(FILES$,LA,3,IER)
IF (IER.NE.0) STOP
IF (LA.EQ.0) GOTO 10
FMODE$ = PARS$(FILES$,LA,3,IER)
IF (IER.NE.0) STOP
GOTO 20
10 CONTINUE
WRITE(6,200)
200 FORMAT(//,10X,'NO FILEMODE WAS ENTERED, A1 ASSUMED')
FMODE$ = A1
CONTINUE
CALL FRTCMS('FILEDEF',FILE,'DISK',PNAME$,FTYPE$,FMODE$)
RETURN
END
SUBROUTINE SETUP

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REAL*8 FN,PT,IPRT
COMMON /HILLS/ XC(100),PEAK(100),SX(100),SY(100),RHO(100)
COMMON /HILLS/ SCALE(100),TWO RHO(100),TWOSCL(100),BASE
COMMON /HILLS/ NHILLS
COMMON /COUNT/ KH,KHW,KV,KN,KGRS,KELL,KINT
COMMON /GRID/ LST(10,10),NHL(10,10),LISTH(450),KHREP(100),KTREP
COMMON /HILL READS/ YMC(100)
SUBROUTINE HILL READS IN THE TERRAIN DATA FROM A SPECIFIED DATA FILE
IF(IPRT.GE.10)WRITE(6,388)
FORMAT('*****ENTERED SUBROUTINE SETUP*****')
CALL SELECT
L=7
READ(L,*) NHILLS
NHILLS IS THE TOTAL NUMBER OF HILLS
READ(L,*) BASE
BASE IS THE SURFACE REFERENCE PLANE, SEAL LEVEL FOR ME
DO 50 I=1,NHILLS
  READ(L,*) XC(I),YC(I),PEAK(I),SX(I),SY(I),RHO(I)
  XC(I) AND YC(I) ARE THE X AND Y COORDINATES OF THE CENTER OF HILL
  PEAK(I) IS THE MAXIMUM ELEVATION OF HILL I
  SX(I) AND SY(I) ARE THE STANDARD DEVIATIONS IN X AND Y OF HILL I
  RHO(I) IS THE CORRELATION BETWEEN X AND Y FOR HILL I
CONTINUE
READ(L,*) LST
LST IS A POINTER FOR WHERE TO START ON LISTH
READ(L,*) NHL
NHL IS AN ARRAY HOLDING HOW MANY HILLS ARE IN THE CORRESPONDING
GRID SQUARE
READ(L,*) NHTOT
NHTOT IS THE TOTAL NUMBER OF HILLS ENTERED IN LISTH (LESS THAN 450)
READ(L,*) (LISTH(I),I=1,NHTOT)
A LIST OF WHICH HILLS AFFECT WHICH GRIDSQUARE
DO 65 DO 100 I=1,NHILLS
  YMC(I)=XC(I)
  YMC(I)=YC(I)*1829.27
  YC(I)=YC(I)*1829.27
  TWO RHO(I)=2.*RHO(I)
  SCALE(I)=-1./SCALE(I)-RHO(I)**2)
  TWOSCL(I)=2.*SCALE(I)
  KHREP(I)=-2147483600
  KTREP(I)=-2147483600
  C ALL VALUES NOW IN METERS ON 0 -- 10,000 GRID
100 CONTINUE
KTREP=-2147483600
KH=0
KHW=0
KV=0

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389      KN=0
      KGRS=0
      KELL=0
      KINT=0
      IF (IPRT.GE.10) WRITE(6,389)
      FORMAT(' ***** LEAVING SUBROUTINE SETUP*****')
      RETURN
      END
      SUBROUTINE SE2PD (SE,NP,IPF,PDET)
      REAL PF(15,4) /3.8,1.9,0.8,0.0,0.5,-1.0,-1.3,-1.8,-2.0,-2.2,-4.0
      +,-5.5,-6.5,-7.1,-7.6,5.1,3.1,2.0,1.2,0.1,2.0,0.8,0.2,-0.2,-0.5,-0.8,-1.0,
      +,-2.9,-4.5,-5.5,-6.0,-6.4,6.1,4.0,3.0,2.2,1.7,1.1,0.8,0.5,0.0,-0.1,
      +,-2.0,-3.5,-4.5,-5.2,-5.5,7.0,4.9,3.8,3.0,2.3,1.9,1.4,1.0,0.8,0.5,
      +,-1.3,-3.0,-4.0,-4.5,-5.5,
      ROUTINE CALCULATES PROBABILITY OF DETECTION, GIVEN A SPECIFIED
      SIGNAL EXCESS BASED ON THE NUMBER OF PULSES PER SWEEP
      AND A SPECIFIED PROBABILITY OF FAILURE (TAKEN FROM BELOW).
      IPP{1} IS 10E-4
      IPP{2} IS 10E-6
      IPP{3} IS 10E-8
      IPP{4} IS 10E-10
      I=15
      IF (NP.LT.900) I=14
      IF (NP.LT.700) I=13
      IF (NP.LT.500) I=12
      IF (NP.LT.300) I=11
      IF (NP.LT.150) I=NP/10
      IF (I.LT.1) I=1
      RHU=PF(I,IPF)
      USING BLAKE'S RESULTS OF NRL RPT 6930, AS IN W.E.S.
      Z=(SE-RHU)/7.
      PDET=1.0-.50*(ERF(-Z*.7071067690)+1.00)
      RETURN
      END

```

CCCCCCC

C

APPENDIX B

SUBROUTINE DIRECTORY

The following subroutines are used in this project:

A. BEACH

This subroutine determines if a point of land is adjacent to the sea.

IX and IY are the X and Y coordinates in array A

A is the map array, dimensioned N by M

KOAST is the returned value

B. BRTN

This routine calculates the geometric cross section of an area of land the size of a resolution cell which may contain a target.

X1,Y1 are the position of the radar

X2,Y2 are the position of the beach

RRES is the range resolution

ARES is the angular resolution

TMAC is the terrain elevation

ECS is the effective radar cross section of the beach

C. ECURVE

This subroutine computes the elevation reduction caused by the earth's curvature present at a given range.

EER is the effective earth radius in meters

RANGE is the distance traveled along the earth

DROP is the loss in elevation resulting from the earth's curvature

D. ELEV

This routine determines the elevation at a given location.

X,Y are the coordinates of the point

TMAC is the returned elevation

E. ELEVG

This routine is similiar to ELEV, but it also calculates the gradient components.

GX AND GY are the calculated components of the gradient.

F. GETSE

This routine processes radar data to compute the signal excess returned to the radar from a contact under the specified conditions.

SE is the returned signal excess

G. INPUT

This routine reads in the radar, target, environmental, and detection data, either from the terminal or from a data file. (the variables are listed in order of appearance in the subroutine)

RDR\$	name of the radar system
PTR	peak transmitted power
B	receiver bandwidth
PRR	pulse repetition rate
BW	horizontal beam width
BV	vertical beam width
ARES	angular resolution
G	antenna gain
SW	angular width of swept sector
ARR	scan rate
PL	pulse length
FREQ	frequency
HR	radar antenna altitude
TMICA	radar antenna altitude
RX,RY	coordinates of radar
W	wavelength
NP	number of pulses illuminating a target per sweep
TGT\$	identifier for target

HT	vertical size of target
SIZES	vertical size of target
DISP	target maximum displacement
TCS	target radar cross section
ISTR	ducting strength code letter
IPF	probability of failure code letter
PDET	required probability of detection for a single sweep
SE	signal excess required to give a desired PDET
HW	significant wave height
C	clutter factor
RL	system loss factor
RNF	receiver noise figure
RMIN	minimum range
RRES	range resolution
RMAX	maximum unambiguous range
RHORIZ	radar horizon

H. INTRO

This is the initial page display.

I. KOVER

This routine is only used internally by LOS

J. LAND

This subroutine determines if a point would be masked by return from land in either the main beam adjacent to the given point, or by land at the appropriate point in a side lobe.

MASK is the returned value, one if there is masking, zero otherwise.

K. LOS

This routine calculates the line-of-sight in terms of a fraction visible for observer-target pairs. (the variables are listed in the order of appearance in the subroutine)

XA,YA (XB,YB) are the X,Y coordinates on the field for A and B.

TMACA (TMACB) are terrain elevation for A (B)

TMICA (TMICB) elevation of A (B).

SIZEA (SIZEB) vertical dimension of A (B).

LATOB (LBTOA) indicator variable for LOS calls.

HHW is the height of the obstructing hill (if any).

WRANGE is the range from the radar to the obstructing hill (if any).

VISFRA (VISFRB) fraction of SIZEA(SIZEB) which can be seen
by B(A).

L. OBGAIN

This routine calculates the "obstacle gain created by the
radio waves being defracted over hill tops.

H1 elevation of the radar
H0 elevation of the hill
H2 elevation of the target
D1 range from the radar to the hill
D2 range from the hill to the target
RLAMDA wavelength
OBGN returned obstacle gain

M. \$PARS

This routine is by Mark Yount. It splits a double-precision
string down into its separate words.

N. RANGE

This routine finds the range between (X1,Y1) and (X2,Y2) in
a plane.

RANGE is returned.

O. RMAP

This routine prepares contour maps with special symbols to be displayed either on the terminal, in response to locations keyed in, or on a line printer. RMAP is composed of three subroutines: PREMAP, PSTMAP, and PRTMAP.

A is the array to be plotted, dimensioned N by M
SPNM is the number of nautical miles between sample points on the grid.

P. SELECT

This routine defines the data files so that the program may access them. Written with assistance from Mark L. Yount.

Q. SETUP

This routine reads in the terrain data from a predesignated data file. (the variables are listed in the order they appear in the subroutine)

NHILLS total number of hills

BASE surface reference plane

XC(I) and YC(I) are the x,y coordinates of the center of the hill

PEAK(I) is the maximum elevation of hill I.

SX(I) and SY(I) are the standard deviations in X and Y of hill I.

RHO(I) correlation between X and Y for hill I
LST pointer on where to start reading on LISTH
NHL array holding how many hills are in corresponding
grid square
NHTOT total number of hills in LISTH
LISTH a list of which hills affect which gridsquare

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- 8